Labor Scarcity, Finance, and Innovation: Evidence from Antebellum America*

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June 26, 2018

Abstract

This paper establishes labor scarcity as an important economic channel through which access to finance shapes technological innovation. We exploit antebellum America, a unique setting with (1) staggered passage of free banking laws across states and (2) sharp differences in labor scarcity between slave and free states. We find that greater access to finance spurred technological innovation as measured by patenting activities, especially in free states where labor was relatively scarce. Interestingly, in slave states where slave labor was prevalent, access to finance encouraged technological innovation that substituted for free labor, but discouraged technological innovation that substituted for slave labor.

Keywords: antebellum America, free banking laws, finance and innovation, labor scarcity

*We are grateful to Andres Almazan, Ramin Baghai, Charles Calomiris, Michael Ewens, Carola Frydman, Matt Jaremski, Debarshi Nandy, Jordan Nickerson, Philip Strahan, Miao Ben Zhang, as well as seminar and conference participants at 2017 WAPFIN@Stern, 2018 Texas A&M Young Scholars Finance Consortium, 2018 Chicago Financial Institutions Conference, 2018 Texas Finance Festival, 2018 University of Kentucky Finance Conference, 2018 SFS Cavalcade, 2018 WFA Conference, Cornell University, Arizona State University, and University of Calgary for helpful comments. Contact information, Mao: ym355@cornell.edu; Wang: Jessie.Jiaxu.Wang@asu.edu.

1 Introduction

While technological innovation is important for economic growth (Aghion and Howitt, 1992) and firms' competitive advantage (Porter, 1992), 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, Fazzari, and Petersen, 2009; Hall, 2010; Hsu, Tian, and Xu, 2014; Kerr and Nanda, 2015). However, 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), among others, the 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 higher capital supply, the degree to which firms utilize capital to advance innovation remains a question.

In this paper, we fill a gap in the literature by examining the marginal effect of finance on innovation in the presence of cost reduction incentives. In particular, we focus on labor scarcity, which leads to high labor costs and hence to strong incentives for firms to adopt labor-saving technologies.

We study a unique historical episode, antebellum America. This fascinating period in the 19th century, from just after the War of 1812 up to the beginning of the Civil War in 1860, provides a unique laboratory for our test. This period witnessed the staggered passage of the free banking laws across eighteen states, a unique setting in which to identify banking shocks. In 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 cumbersome and corrupted, aiming at protecting the interests of incumbent banks. Between 1837 to 1860, eighteen 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' access to local

[1] Rosenberg (1969) argues what motivates inventors to invent certain things appearing throughout the 1800s and early 1900s is that 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 expending resources with the purpose of reducing their costs. Mokyr (2010) documents the cost reduction of many goods due to technological innovation for 1750–1914, such as costs of fuel, steel, energy consumption, and transportation. Another example is the role of innovation in computer technology in reducing computational and labor cost, as documented and predicted by Moore's law (Schaller, 1997).

finance.

Furthermore, labor scarcity differed significantly between the slave states in the South and the free states in the North. We document that at the margin "slave labor" in the South was less expensive than the "free labor" in the North.[2] In other words, labor scarcity was more severe in the free states than in the slave states. The sharp contrast in labor scarcity was reinforced by the immobility of labor across regions during that time—another feature of antebellum America that is distinct from today's world.

We propose a stylized model to understand how access to finance and labor scarcity jointly affect innovation. The model builds on Acemoglu (2010) and links the equilibrium innovation level with labor and finance. The economy has a monopoly entrepreneur who innovates new technology and manufactures machines that embody the patented technology.[3] The representative final goods producer combines labor and the new technology in production and maximizes profit by optimizing the demand for labor and machines. The entrepreneur faces a setup cost for manufacturing the new technology and earns monopoly profit. Given the demand for machines, she chooses the level of innovation and the monopoly price for machines. In particular, labor scarcity drives producers' demand for the labor-saving technology; greater access to finance reduces the entrepreneur's cost of manufacturing the technology. We show that the equilibrium innovation outcome is jointly determined by labor scarcity and access to finance. The model has three predictions. First, greater access to finance spurs innovation. Second, if labor scarcity remains constant or becomes more severe when access to finance is greater, the equilibrium innovation level increases. Finally, if labor scarcity becomes less severe when access to finance is greater, then equilibrium innovation can actually decrease.

We combine several novel data sources to test the hypotheses. First, using digitized historical

[2]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.

[3]In this paper, 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), the specific episodes of the 19th century America were mostly concerned with labor-saving technologies. The well-known Habakkuk hypothesis (Habakkuk, 1962) in economic history argues that the rapid technological progress in the 19th century US owned to labor scarcity, which acted as a powerful inducement for the adoption of labor-saving technologies, and more broadly for innovation. "...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) 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)

patent filings from the United States Patent and Trademark Office, we collect data on the historical patenting activities to proxy for technological innovation in the antebellum period. From the patent filings, we are able to identify, the county and state of the inventor who files the patent, the grant year and the technology class of the patent.[4] Second, using data and historical records about antebellum banks, we obtain the name of the bank, its charter type, the location of operation, entry and exit dates, as well as detailed balance sheets. These historical data allow us to directly observe changes in banking activities following the passage of the new banking laws. Finally, we obtain social and economic variables at the state level from the decennial census and the census of agriculture and manufacturing.

In the baseline analysis, we examine whether access to finance spurred innovation in antebellum America. We employ a difference-in-differences (DD) approach, taking advantage of the staggered passage of the free banking laws. Our baseline result shows that, 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 11.6 more patents in the third year following free banking, which accounts for 15.4% of the state-level patent variability. The results are robust to controlling for state fixed effects, year fixed effects, and time-varying state-level demographic and economic variables.

We then conduct a battery of tests to investigate whether our baseline results indeed show a causal impact of free banking on innovation. First, while the passage of free banking laws created exogenous changes to access to finance, state-level factors that manifested differently across states could have affected the timing of the banking reform. To mitigate the reverse causality concern, we employ the methodology of Bertrand and Mullainathan (2003) to examine the dynamics of innovation surrounding the passage of free banking laws. 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 from the empirical distribution of years when states passed the free banking laws and re-estimating our baseline specifications:

[4]Information on patent citation or application year is not available for these historical patents. While we acknowledge that patent filings do not equal innovation, they seem to be a reasonable and best available measure of antebellum innovation according to economic historians (Griliches, 1990; Sokoloff, 1992; Lamoreaux and Sokoloff, 2000).

we conclude that the regression coefficients we estimate in our main tests are results that cannot occur mechanically in the data. Finally, we control for contemporaneous events that might have affected a state's innovation, such as usury laws and the presiding political party in a state. Our baseline results continue to hold with these controls, thus ruling out potential sources of confounding effects.

Having established that access to finance spurred innovation, we next turn to the role of labor scarcity as an important economic channel. Conjectured by 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 first take advantage of the sharp differences in labor scarcity between the free and slave states. In free states where slavery was prohibited, production was carried out by "wage labor" and labor was relatively scarce. In contrast, in slave states, slaves not only provided labor that could not resign or demand higher wages, but ensured a source of labor for generations. In other words, there was higher labor scarcity in free states. We hypothesize that the impact of free banking was higher in free states, where labor was relatively scarce. This is indeed what we find.

To further pin down the labor scarcity channel, we introduce patent industry in a triple difference-in-differences (DDD) framework. Since free states and slave states differed in many dimensions other than labor scarcity, we introduce patent classification to control the comparison. In particular, we exploit the differences in the labor scarcity across agricultural industry and manufacturing industry in the free states and slave states. We find that, following the passage of free banking laws, the manufacturing patents in the free states experienced the highest increase. What is perhaps less expected is the response of innovation in slave states. While the manufacturing patents in the slave states increased with free banking, the agricultural patents actually experienced a slight decline.

The findings are consistent with the theoretical predictions. In the free states, free banking led to greater access to finance by merchants and manufacturers. The expansion of the manufacturing industry 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 labor

population as banking made slavery investment and trade more convenient. With a greater supply of slave labor, incentives for innovation were further weakened. Indeed, we find an increase in slave labor following the passage of the free banking laws in a state. The results generally follow our model's conjecture that finance promotes innovation when labor is scarce and may impede innovation when labor becomes more abundant.

Although we have compared innovation across industries within the free and slave states, we are concerned that different states might have different industry concentrations, which could render innovation not comparable for these states. Hence, we further restrict the sample to states with similar industry concentrations in manufacturing and agriculture. Our results continue to hold in these subsample tests.

Having established the role of labor scarcity in how finance affects innovation, we take a step back and examine whether the passage of free banking laws did improve access to finance. We find that there was a significant increase in the number of free banks and the number of loans issued by free banks after the passage of the free banking laws. In addition, the impact of the free banking laws on access to finance and innovation was positive and significant when we only focus on slave states, suggesting the results are not driven by free states. Overall, the results indicate that the passage of free banking laws indeed led to an improvement in access to finance.

Our paper sheds new light into factors driving technological innovation. The insights are useful today in explaining, for example, why some regions are more innovative than others, and under what conditions additional financing resources are effective in spurring innovation.

Our paper contributes to the literature on the finance-growth nexus. This literature show a positive link between financial development and economic growth, both theoretically (Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991) and empirically (King and Levine, 1993; Jayaratne and Strahan, 1996; Levine, 1997; Beck, Levine, and Loayza, 2000; Black and Strahan, 2002; Kerr and Nanda, 2009; Ewens, Nanda, and Rhodes-Kropf, 2018; Ewens and Farre-Mensa, 2018). In particular, several studies use banking deregulation in the 1970s to 1990s U.S. to study the effect on innovation (Chava, Oettl, Subramanian, and Subramanian, 2013; Amore, Schneider, and Zaldokas, 2013; Cornaggia, Mao, Tian, and Wolfe, 2015; Hombert and Matray, 2016). In contrast to these studies, 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. This unique testing ground provides us new evidence on the impact of bank deregulation on technological innovation. Moreover, the immobility of labor and heterogeneity in labor scarcity across states allow us to establish labor scarcity as a new economic channel, absent from previous studies of the finance-innovation nexus.

Second, we provide 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 (2002, 2010) formalize the role of factor price in directing innovation and technical change. Bena and Simintzi (2017) study the 1999 U.S.-China bilateral agreement and find that cheap offshore labor crowds out labor-saving innovation. Tuzel and Zhang (2018) find that investment tax incentives encourage computer purchases but reduce routine-task jobs. 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 U.S. Civil War (Hanlon, 2015). Adding to this literature, we provide new evidence confirming the role of labor scarcity in shaping innovation. Unlike earlier studies, our empirical setting features the interaction between labor scarcity and access to finance.

Finally, this study adds to an assessment of the effect of free banking. The economic value of free banking, which some have nicknamed "wildcat banking," has been debated by economic historians.[5] Jaremski and Rousseau (2013) study the effects of free banking on economic growth using decennial census data. Conclusions drawn from such studies are subject to data limitation since the law's passage was clustered in two decades and economic growth measures are only available at a decennial frequency. In contrast, patenting activity can be measured annually, which provides a more granular reflection of economic growth via technological advances.

This paper proceeds as follows. Section 2 presents the historical background. Section 3 sets up a model to analyze the effect on innovation of greater access to finance under different labor scarcity conditions. Section 4 describes our data. Section 5 presents the main empirical results on free banking and innovation, and Section 6 highlights labor scarcity as the key economic

[5]See for example Rockoff (1972), Rockoff (1974), Rolnick (1983), Rolnick and Weber (1985), Ng (1988), Bodenhorn (1990), Hasan and Dwyer (1994), Economopoulous and O'Neill (1995), Jaremski (2010), Atack, Jaremski, and Rousseau (2014), and Mitchener and Jaremski (2015).

channel. Robustness and extensions are in Section 7. Section 8 concludes.

2 Historical Background

2.1 Antebellum America

The antebellum era in the United States 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 economy differed greatly across regions, especially between the free states in the North and the slave states in the South.

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) labor became wage earners. For example, textile factories hired and trained employees to run the looms, which gradually began overtaking apprenticeships and family members as workforce sources. In contrast, there were relatively few people willing to work for wages in agriculture so farm labor was in shortage (Rosenbloom, 2018).

In the agricultural South, slaves were the major labor force. The cotton boom made plantations profitable. Farmers obtained cheap land and used slave labor to grow and harvest the crops. Cotton growing became so profitable for the planters that it greatly increased their demand for slave labor. In fact, most plantation owners' investments and wealth were in their slaves. With this continuing demand, the number of slaves in America grew from 700,000 in 1790 to 4 million in 1860.

Because slaves were denied formal education, slave labor contributed primarily to the low-skilled, agricultural labor force. Unlike wage laborers, slaves could not resign or demand higher wages, and their progeny ensured a supply of labor for generations. Slaves were mobile, being traded between slaveholders.[6] 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).[7] Far from stagnating, the economy of the antebellum South grew

[6] For example, New Orleans was the largest city in the South and the site of its largest slave market (Calomiris and Pritchett, 2009, 2016).

[7] ...the selling states include Virginia, Maryland, Delaware, North Carolina, Kentucky, and the District of

rapidly. Between 1840 and 1860, per capita income increased more rapidly in the South than in the rest of the nation. By 1860 the South had attained a level of per capita income that was high by the standards of the time (Fogel and Engerman, 1974; Fogel, 1977).

2.2 Antebellum Innovations

The antebellum era was a time of great technological change. Technological innovations, such as the steam engine, mechanical reaper, and sewing machine, reshaped the production process in and after the middle third of the 19th-century (Thomson, 2004). The boom in patenting is consistent with an emphasis on demand-induced advances in inventive activity. 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). Rising labor costs acted as a powerful inducement for the invention and diffusion of labor-saving technologies. For example, Singer, in New York state, patented the first practical and efficient sewing machine in 1851 (patent No. 8,294). The improvement 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 the states of New York, Pennsylvania, and Ohio, where farm labor was in scarcity.[8]

Notably, the growth in patenting was marked by a disproportionate increase in inventions by ordinary citizens with relatively common skills and limited wealth rather than by those with rare technical expertise or extensive financial resources (Sokoloff and Khan, 1990).[9]

Behind the strong innovative activity was a solid patenting system that transmitted knowledge of technological solutions and provided avenues for commercializing innovations.[10] The Patent Act of 1790 was the first federal U.S. patent statute. The amendment of the act expe-

Columbia; the buying states are assumed to be 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).

[8] In contrast, in the Southern plantations, winnowing was initially done by hand using winnowing baskets and then by winnowing barns, both replying intensively on slave labor (see Littlefield, 1991).

[9] Using U.S. patent records from 1790 to 1846, Sokoloff and Khan (1990) find shifts in the distributions of patentees from merchants/professionals to artisans/tradesmen and from urban to rural residents and a rising share of patents to patentees with no specialization and few patents over their careers.

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

dited the examining process: on average, it took several months for a patent to be examined and granted once a written application was submitted.

2.3 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.[11] 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 supporters then lobbied heavily against the formation of new, competing banks. As a result of this process, 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 (see Lamoreaux, 1986; Schweikart, 1987a; Lamoreaux, 1996).[12]

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 eighteen states

[11] 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.

[12] Lamoreaux (1996) traces the early history of the banking system to the antebellum era and documents the pervasiveness of insider lending.

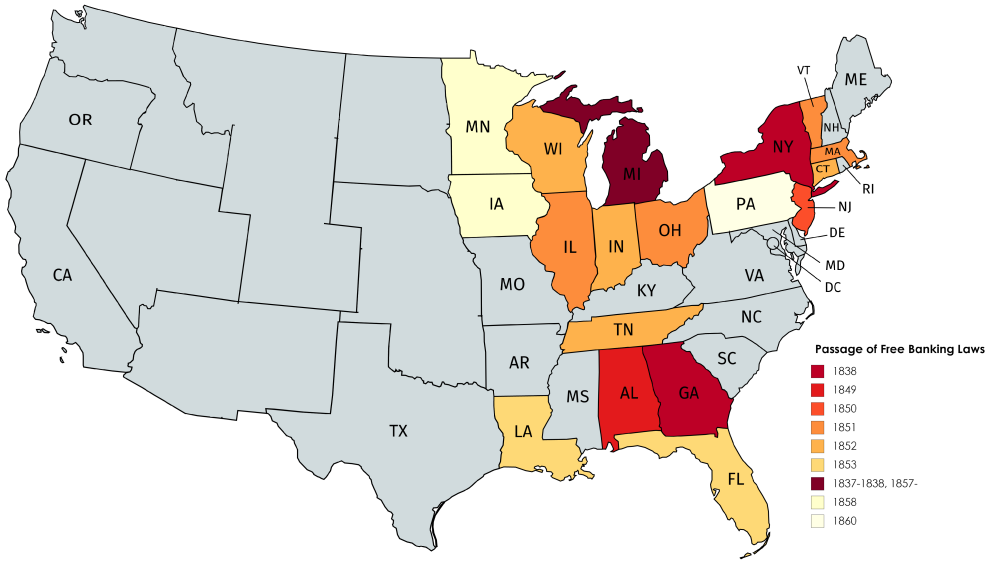


Figure 1. The Passage of the Free Banking Laws across States

(Rockoff, 1974). Figure 1 shows a timeline of the staggered passage of the free banking laws.[13] The list of passage years are also presented in Table 1, Panel B. 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, 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.

The passage of the free banking laws was followed by greater access to finance in that state. Bank entry accelerated after the passage of the laws (Economopoulous and O'Neill, 1995). Panel

[13] The states shown in the map were established as states or territories either before or during the free banking era and their economic data were included in the census beginning in 1850. For example, statehood was granted to California, Oregon, and Texas in 1850, 1859, and 1846 respectively.

[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 (see Rolnick, 1983).

B in Table 1 shows the bank entry statistics after the passage years. The new banks had wider geographic coverage and a larger customer base than the existing charter banks (Bodenhorn, 2000). They entered rural, previously unbanked areas.[15] The free entry improved the allocation of bank capital and encouraged the establishment of commercial businesses, manufacturing, and small businesses (Rockoff, 1974).[16] And finally, lower barriers to entry and increasing competition also made existing charter banks more efficient and competitive.[17]

Microlevel data shows that some of these free banks acted as innovation-inducing Schumpeterian financier and engine of growth (Bodenhorn, 1999). 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 of Watertown 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 construction firms were overrepresented. 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. Instances of other successful local innovators financed by the bank include Hotchkin who established a tannery and harness manufactory in Watertown in late 1854 and Remington who established the Remington paper mill in 1853 (Emerson, 1898, p.335–360).

Importantly, the passage of the free banking laws was plausibly exogenous to the innovation in a state. Historians have not yet reached consensus on the factors that determined where

[15] Following the passage of the free banking laws, 14.8% of previously unbanked counties had bank entrance, and 11.5% of previously unbanked counties had free bank entrance during our sample period (1812-1860).

[16] In its encouragement of small business, 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).

[17] 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..."

and when the laws were passed. Some view the passage of the laws as a result of political interference, corruption, and bargaining power between different political parties (Bodenhorn, 2006; Du, 2010; Murphy, 2017). Furthermore, the panic of 1837, financial distress and economic depression that followed it, accelerated that process (Calomiris and Haber, 2014).[18]

In some states, it seemed to be initiated by random events. An interesting example is the state of New York. 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 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" (Bodenhorn, 2006, p. 21).

In our empirical analysis, we formally test and show that the passage across states cannot be explained by demographic and economic conditions, nor political factors.

3 Model and Implications

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

3.1 Model Setup

Environment The economy has a monopoly entrepreneur and a representative final goods producer. The entrepreneur innovates new technology and manufactures machines 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 the 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 argued in earlier sections, antebellum America was mostly concerned with demand-induced labor-saving technologies. Hence, we model technology θ as a labor-substitute such that $\partial^2 F/\partial L \partial \theta < 0$. The term F is combined with machines that embody technology

[18]The North and the South had very different banking systems. The North had the unit banks, and the South favored branching banking. The capital mobility associated with branch banking helped move crops and slave labor to its highest use (Calomiris, 2006). The fact that the South favored branch banking strengthens the random nature of the passage of free banking laws in a state.

θ, the quantity of which is denoted by q. The term $\alpha^{-\alpha}(1-\alpha)^{-1}$ is included as a convenient normalization.

With monopoly power, the entrepreneur manufactures machines that embody the patented technology. The cost associated with manufacturing the new technology is $C(\theta, \gamma)$. This is a one-time setup cost for the entrepreneur on, e.g., research and experimentation, installing new tools for manufacturing, constructing prototypes, marketing, gathering information for demand, etc. The cost size depends on two parameters, such that $\partial C(\theta,\gamma)/\partial\theta > 0$, $\partial^2 C(\theta,\gamma)/\partial\theta^2 > 0$, and $\partial C(\theta,\gamma)/\partial\gamma < 0$. The parameter γ summarizes the entrepreneur's access to local finance. Greater access to local finance reduces this one-time cost for the entrepreneur. As discussed in earlier sections, the benefit of greater access to local finance to an entrepreneur can come from different channels. For instance, the entrepreneur may face lower financing cost for manufacturing the new machines.[19] She may also find it easier to acquire information and market for the new technology with a banker in town. Notice that the benefit does not require that the entrepreneur is financially constrained in financing the research and development cost and patent application costs. Once developed and patented, the entrepreneur has monopoly power in the technology market; she 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, the labor supply $\bar{L}$ is exogenously given.

Optimization Taking wage w and the unit price of machine χ as given, the representative final goods producer chooses demand for labor and machines to maximize profits; thus, she solves the following problem:

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

[19] In the model, we assume the entrepreneur files the patent and manufactures the technology. In practice, the innovator and the manufacturer could be two separate agents. For a patent to be profitable to file, there must be a corresponding product market and a financially sound 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 earn royalty.

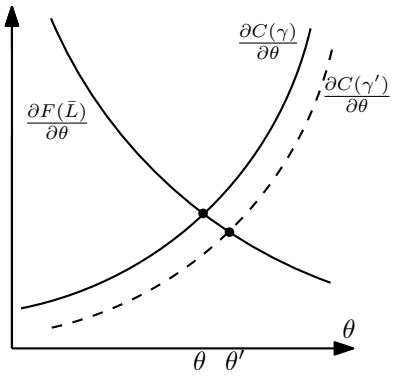


Figure 2. The Effect of Greater Access to Finance. This figure illustrates how the equilibrium innovation θ responds to greater access to finance. The horizontal axis represents θ. The downward sloping curve, $\partial F(\bar{L}, \theta)/\partial\theta$, is the marginal product of labor. The upward sloping curve, $\partial C(\theta, \gamma)/\partial\theta$, is the marginal cost of manufacturing the new technology. Greater access to finance shifts the curve $\partial C(\theta, \gamma)/\partial\theta$ downward, moving θ to θ'.

The first-order condition with respect to q gives the optimal demand for machines, an inverse demand curve with constant elasticity,

$$q^* = \alpha^{-1} F \chi^{-\frac{1}{\alpha}}. \tag{2}$$

Given the demand for machines (2) and the cost for manufacturing the new technology, the monopoly entrepreneur then chooses the level of technology θ and the monopoly unit price χ,

$$\max_{\theta,\chi} \left(\chi - (1-\alpha)\right) q - C(\theta, \gamma) \tag{3}$$

Equilibrium An equilibrium in this economy consists of: the final goods producer's decisions $\{L^*, q^*\}$, the entrepreneur's decisions $\{\theta^*, \chi^*\}$, and wage 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 (3) given the demand for machine q^*; w^* satisfies labor market clearing such that $L^* = \bar{L}$.

Factors driving innovation First we plug the machine demand q^* in (2) into the entrepreneur's problem (3). This gives the profit maximizing price of the entrepreneur, $\chi^* = 1$. Substituting χ^* and q^* into (3), the entrepreneur's problem reduces to $\max_{\{\theta\}} F(\bar{L}, \theta) - C(\theta, \gamma)$. Equivalently, the equilibrium innovation θ^* satisfies

$$\frac{\partial F(\bar{L}, \theta)}{\partial \theta} = \frac{\partial C(\theta, \gamma)}{\partial \theta}. \tag{4}$$

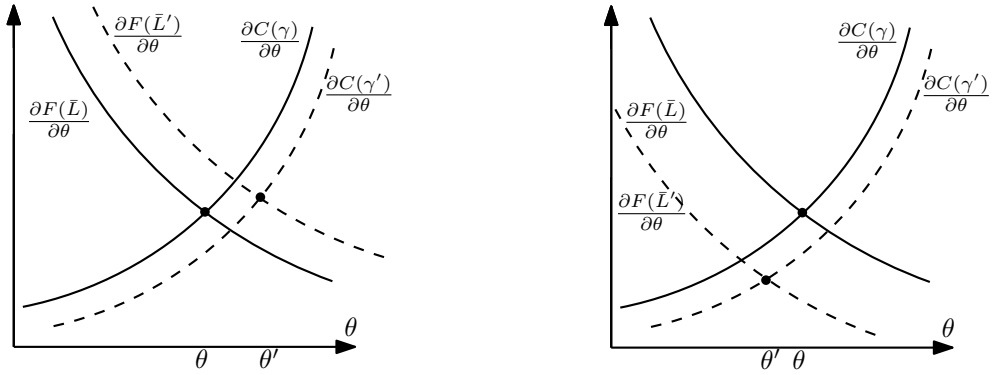
From Eq. (4), access to finance and labor supply are two factors jointly determining equilibrium innovation.

3.2 Model implications

The model delivers the following implications. The first implication is the effect of greater access to finance. Eq. (4) implies that in the model, $\partial\theta^*/\partial\gamma > 0$. Other things equal, greater access to finance reduces the cost of manufacturing new technology and spurs innovation. The effect is shown in Figure 2. The horizontal axis represents θ. The downward sloping curve, $\partial F(\bar{L}, \theta)/\partial\theta$, is the marginal product of labor. The upward sloping curve, $\partial C(\theta, \gamma)/\partial\theta$, is the marginal cost of manufacturing new technology. The equilibrium level of innovation is achieved where the two curves cross. With greater access to finance, the manufacturing costs decrease; hence, $\partial C(\theta, \gamma)/\partial\theta$ shifts downward, leading to a higher level of innovation.

The implications are more subtle when labor supply interacts with access to finance. If labor supply decreases or remains unchanged following greater access to finance, the equilibrium innovation level increases. This is shown in Figure 3a. A more severe labor scarcity shifts the marginal product of labor upwards, further increasing θ. An interesting case is when labor scarcity relaxes following greater access to finance. As shown in Figure 3b, larger labor supply pushes the marginal product of labor downward. If this channel dominates, the equilibrium innovation could decrease, despite a drop in technology manufacturing costs.

Let us apply the model's implications to antebellum America. In the industrial North, free banking led to greater access to finance by local merchants and manufacturers. The expansion of businesses and the boom in industrialization likely posed a higher degree of labor scarcity. From Figure 3a, we should expect an increase in innovation, unambiguously. The effect on technologies that substituted for free labor in the South would be similar. In contrast, the technologies that substituted for slave labor in the South would be an exception. If an increase in slave labor coincided with free banking, even if not causal, we could expect a decrease in technologies that substituted for slave labor.



(a) More severe labor scarcity.

(b) Less severe labor scarcity.

Figure 3. Labor Scarcity and Greater Access to Finance. This figure illustrates how the equilibrium innovation θ responds to greater access to finance when labor scarcity condition also changes. In (a), labor scarcity becomes more severe with an increase in γ; in (b), labor scarcity becomes less severe with an increase in γ.

4 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. We next describe the data sources and provide summary statistics.

4.1 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. The historical records provide the year in which the patent was granted, the state and county where the inventor resided, and the technology class the patent belonged to.[20] The blue dotted curve in Figure 4 shows the natural log of total patent counts by year from 1812 to 1860. While the initial growth was slow, a span of rapid growth in patenting 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 (Sokoloff and Khan, 1990). 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

[20]Information regarding patent citation or application year is not available for historical patents in the Antebellum era.

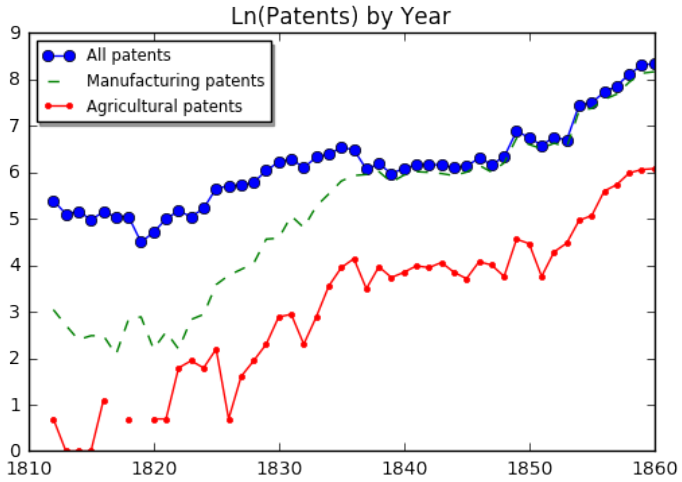


Figure 4. The Total Number of Patents Granted. The blue dotted curve shows the natural log of total patent counts by year from 1812 to 1860. The red dotted curve and the green dashed curve show the natural log of agricultural patents and manufacturing patents, respectively.

a 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 the patent belonged to allows us to identify technologies used in the agricultural industry and manufacturing industry, respectively. We begin by mapping the USPTO technology classes into two-digit technological sub-categories and six main categories following Hall and Jaffe (2001). Agricultural patents then consist of those that fall into sub-category 11 (Agriculture, Food, Textiles) and 61 (Agriculture, Husbandry, Food). Manufacturing patents consist of those that fall into main category 5 (Mechanical) as well as sub-category 63 (Apparel & Textile).[21] The red dotted curve and the green dashed curve in Figure 4 show the log of agricultural patents and manufacturing patents, respectively. The manufacturing patents had a larger quantity and experienced faster growth than the agricultural patents.

While we acknowledge that simply counting the number of patents could miss certain valuable inventions, it seems to be a reasonable and the best available measure of antebellum innovation. Economic historians studying pre-Civil War invention and productivity look primarily at patent counts. They argue that patenting, though an imperfect measure, should be qualitatively

[21] Some other sub-categories potentially do not pertain to labor-saving technologies, such as sub-category 31 (Drugs), 42 (Electrical Lighting), 45 (Power Systems), and 62 (Amusement Devices).

representative of the resources consumed in inventive activity (Griliches, 1990). For example, using census data, Sokoloff (1992), shows that patenting was a major driver of antebellum total factor productivity at the cross section.

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 frictional and segmented during that time. Lamoreaux and Sokoloff (2000) use industry 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.

4.2 Free Banking and Historical 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 year of the law's passage, and equal to one in the year of the passage and afterwards. We allow the value of *Free banking* to revert to zero for Michigan in and after the year of 1840 when the state abolished the free banking laws and before the year of 1857 when the state reinstated the free banking laws again. For the 21 states which did not pass the free banking laws, we set the *Free banking* indicator equal to zero in every year.

We obtain information for banks from Economopoulous and O'Neill (1995) and Weber (2006, 2008) complemented with historical bank records and State Bank Condition Reports found in state reports.[22] We obtain information on the name of the bank, its charter type, the location of operation, entry and exit dates, and detailed balance sheets. Figure 5 shows the total number of free banks (in blue) and charter banks (in green) by year, for the period of 1812–1860. From the figure, we can make the following observations. First, charter banks constituted the majority of the bank population. Second, free banks began to appear in 1837 (the year the first free banking law was passed) and increased sharply in number as the law was approved in subsequent states.

[22]The sources include U.S. Congressional Documents and Bankers' Magazine and Statistical Registrar, Comptroller of Currency Report (1876), Hasse (1957), Dillistin (1942), Campbell (1932), Moore (1927), Caldwell (1935), and Scott (2000). We thank Matthew Jaremski for sharing with us the information on bank charter type.

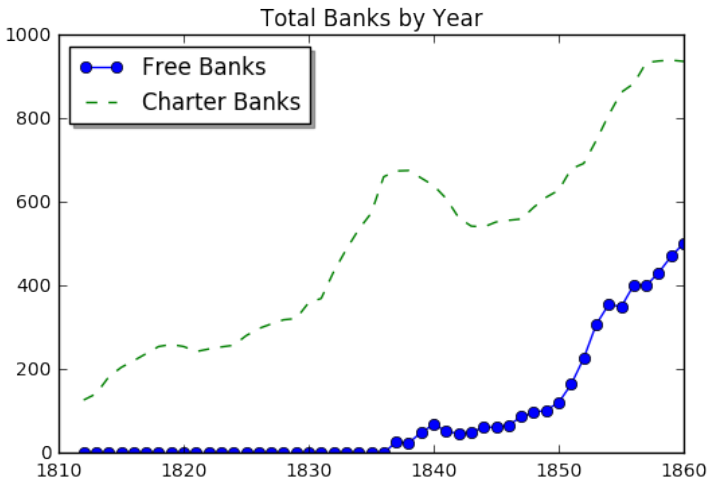


Figure 5. The Total Number of Banks Operating. The blue dotted curve and the green dashed curve show the total number of free banks and charter banks by year, for the period of 1812–1860.

Finally, after the implementation of the free banking laws, the increase in the total number of banks was driven mostly by the entry of the free banks.

For those states that passed the free banking laws, some states had significant free banking activities, whereas others, such as Massachusetts, Vermont, Georgia, Alabama, and Florida had few free bank entry (Ng, 1988). The estimated growth rate of free banks is 19 per year when including controls and year and state fixed effects. When comparing the balance sheets of the free banks with the charter banks, the average size of free banks in total assets and loans was slightly smaller than that of the charter banks, but comparable.

4.3 Historical Census Records

We obtain social and economic variables at the state level from the decennial census of 1810–1860, and the Census of Agriculture in 1840, 1850, and 1860. Given that the variables are decennial, we interpolate and extrapolate them to individual years. In particular, we use the following variables: population, urban population, slave population, white population. In our robustness analysis, we control for economic and industrial characteristics at the state level by using agricultural and manufacturing output.

A state is included in our sample starting from the establishment of the territory or statehood

whichever is earlier.[23] We also include a dummy variable that characterizes whether a state is a slave or a free state based on Wagner, Gallagher, and Finkelman (2009). This dummy variable is not time-varying. The list of states is provided in Appendix A. The slave and free states differ significantly in the degree of labor scarcity. In addition to comparing the demographic features, we take the available wage measures from the decennial census (in 1850 and 1860), including average wages to a day laborer (with board) and average wages to a day laborer (without board).

To measure cost of slaves, we obtain slave hiring rate and purchase rate using the Slave Hires, Slave Sales and Appraisals data put together by Fogel and Engerman (1974).[24]

4.4 Summary Statistics

The summary statistics are provided in Table 1 Panel A. On average, a state in our sample had 25.14 granted patents per year. Among them, 2.27 patents are classified as agricultural patents, and 10.19 patents are classified as manufacturing patents. The average population in a state was 1.1 million. Among them, 12% was urban population, 15% was slave population, and 82% was white population. On average, there were 3.04 free banks in each state and $1.3 million loans issued by free banks each year.[25] The definition of the variables is provided in Appendix B.

5 Free Banking and Innovation

5.1 Baseline Specification and Results

To assess the impact of access to finance on innovation, we estimate the following empirical model:

$$Ln(Patents)_{i,t+s} = \alpha + \beta Free\ banking_{i,t} + \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}, \tag{5}$$

where i indexes state, t indexes time, and s is equal to one, two, or three. The dependent variable in Eq. (5) is the natural logarithm of one plus the total number of patents generated in a state in the following one, two, and three years, respectively. We use a dummy variable, $Free\ banking_{i,t}$ to capture the status of passage of the free banking law in state i and year t.

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

[24] The Slave Hires data are available at https://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/7422. The Slave Sales and Appraisals data are available at https://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/7421

[25] For those states that passed the free banking laws, there were on average 26 free banks and $11 million loans issued by free banks each year.

$Z_{i,t}$ is a vector of controls that include total state population, white population ratio, urban population ratio, and slave population ratio in state i year t. $Year_t$ and $State_i$ capture year and state fixed effects, respectively. We cluster standard errors by year in our baseline tests.

We include state-level controls to absorb the time-varying demographic and economic conditions which could be associated with the inventive opportunities of a state. We include population and urbanization following Higgs (1971). In the absence of a mass communications system, the locational distribution of actual inventive opportunities coincided with that of the population.[26] The slave and white populations reveal, to a large extent, the local educational attainment, social class structure, and division of labor.

We also include the state fixed effects. This helps to address the concern of omitted variables. Unobservable variables omitted from Eq. (5) that generate variation in a state's openness to free banking law might also correlate with innovativeness, rendering our findings spurious. 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 innovativeness and *Free banking*, which could bias our coefficient estimate of *Free banking* upward. Including state fixed effects will strip out any persistent differences across states.

We report the OLS regression results estimating Eq. (5) in Table 2. 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. To be more concrete, based on the coefficient estimate of *Free banking* in column (6), states that passed the free banking law generated a total of 46.3% more patents in the third year than states that did not pass the free banking laws. The effect of free banking laws on patent quantity was economically sizable: the above increase translates to an increase of 11.6 patents three years after the passage of the free banking law. (Table 1 shows the average number of patents granted in a state was 25.1. The product of 25.1 and 46.3% is 11.6.) This increase in patent quantity accounted for 15.4% (=11.6/75.4) of the state-level patent variability, a significant margin.

[26] Higgs (1971) shows that the proportion of the population in urban areas and the number of inventions per capita were closely associated during the 1870–1920 period for a cross section of American states.

The estimated sizable effect of *Free banking* on innovation could take place in both direct and indirect channels. Through direct channels, the free banking laws led to 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. For instance, by examining the borrowers in the discount books of the Black River Bank, Bodenhorn (1999) finds that this free bank operated as an innovation-inducing Schumpeterian bank by directly supporting local young innovators and entrepreneurs. Instances of successful innovators financed by the bank include Bradford who invented the portable steam engine in 1849, Hotchkin who established a tannery and harness manufactory in Watertown in late 1854, and Remington who established the Remington paper mill in 1853 (Emerson, 1898, p.335-360).

The free banking laws could also improve access to finance through indirect channels. Free banking promoted stability to currency as it increased currency circulation. Lower barriers to entry and increasing competition led to a more efficient and competitive charter banking system (Bodenhorn, 1990) and more efficient allocation of bank capital (Rockoff, 1974). More banks also promoted advancement in transportation and commerce (Atack, Jaremski, and Rousseau, 2014).

Table 2 shows that the effect on innovation is already significant in the following year. This is a reasonable result for the antebellum era. First, the antebellum innovations typically did not take too long to invent. For example, Singer invented the first practical sewing machine eleven days after being given a sewing machine to repair. Second, unlike today, it took only several months for a patent to be examined and granted. Finally, it was very likely that the manufacturers of new technology were more sensitive to greater access to finance; when the manufacturers had more resources to invest, the innovators had stronger incentives to patent existing new ideas.

5.2 Additional Endogeneity Tests

5.2.1 Temporal Dynamics of Innovation

In the historical background, we have argued that the staggered passage of the free banking laws represented a plausibly exogenous shock to access to finance. Nonetheless, it is likely that

state-level factors that manifest differently across states could have affected the timing of the passage of free banking laws in different states. A reverse causality concern may arise if the states also differ in their innovation intensity and such differences triggered the passage of free banking law. To further explore the possibility of reverse causality, we follow Bertrand and Mullainathan (2003) to examine the dynamics of innovation prior to the free banking laws. We decompose *Free banking* into four dummy variables associated with four periods around the free banking laws: all years up to and including one year prior to free banking, one year after free banking, two years after free banking, and three 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:

$$\begin{aligned} Ln(Patents)_{i,t+1} =& \alpha + \beta_1 Before^{1-}_{i,t} + \beta_2 After^{1}_{i,t} + \beta_3 After^{2}_{i,t} + \beta_3 After^{3+}_{i,t} \\ &+ \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}. \end{aligned} \tag{6}$$

In Panel B of Table 3 we report the regression results estimating Eq. (6). Across all specifications, the coefficient estimate of $Before^{1-}_{i,t}$ is not significant, suggesting that state-level innovation showed no significant change prior to the passage of free banking laws. The coefficient estimates of $After^{1}$, $After^{2}$, and $After^{3+}$ are positive and significant, consistent with our baseline findings. These results alleviate concerns about reverse causality and suggest that the innovation only increased after free banking.

5.2.2 Falsification Test

Another concern that could prevent us from drawing a causal interpretation of free banking laws on innovation is an omitted variables problem: unobserved shocks or variables that are omitted from our analysis but coincide with state-level free banking events could be driving our results. To resolve this concern, we conduct placebo tests to check whether our results disappear when we artificially assume that free banking laws occurred in years other than the actual passage year. We do this by first obtaining an empirical distribution of years when states passed the free banking laws. We then randomly assign states to each of these passage years (without replacement) following the empirical distribution. This approach maintains the distribution of free banking years from our baseline specification, but it disrupts the proper assignment of free

banking years to states. Therefore, if an unobservable shock occurred at approximately the same time as the free banking laws, it should still reside in the testing framework and thus have an opportunity to drive the results. However, if no such shock exists, then our incorrect assignments of free banking years to states should weaken our results when we re-estimate our baseline regressions in Eq. (5). We report the results in Table 4. The coefficient estimates of *Free banking* are statistically insignificant and not different from zero in all columns, providing support that it is free banking that impacted innovation rather than other shocks.

5.2.3 Evidence Against Alternative Interpretations

Although our falsification test alleviates concerns about confounding effects from contemporaneous events, we conduct additional robustness tests to rule out potential sources of confounding effects.

State Usury Laws. One event that could have taken place simultaneously with the passage of free banking laws was a change in state usury laws. Usury laws limit the maximum interest rate banks can charge on loans. As argued by Benmelech and Moskowitz (2010), usury laws limited the maximum legal interest rate, causing credit rationing. They show that usury laws in the 19th century reduced credit and economic activity when they were binding. The alternative hypothesis is that it was the relaxation of usury laws rather than the free banking laws that led to an increase in innovation: in states with a higher maximum legal interest rate, banks lent with lower restrictions to high-risk entrepreneurs, encouraging innovation. Data on the maximum legal rates come from Holmes (1892). We control for the effect of time-varying usury laws in estimating Eq. (5) and examine whether they could absorb the impact of the free banking law. Panel C of Table 3 reports the results with usury laws controls in columns 1-3. The results indicate that the impact of free banking on innovation was not absorbed by usury laws.

Political Parties in Power. Another factor potentially related to both innovation and banking was the alternation of state-level political parties in power. In particular, the Whig Party, a political party active in the middle of the 19th century, favored modernization, banking, and economic protectionism to stimulate manufacturing. It appealed to entrepreneurs, planters, reformers, and the emerging urban middle class, but had little appeal to farmers or unskilled

workers.[27] Potentially, the probanking Whig Party's election in a state led to both the passage of the free banking laws and other regulations that encouraged entrepreneurship. To investigate this issue, we control for state-level political party in columns 4-6 of Panel C of Table 3. The data are from the historical record on the governors of the states in *The Tribune Almanac and Political Register*.[28] The dummy variable equals 1 if the state governor belonged to any of the following parties: Whig, Anti-Masonic, Republican, American, Know-nothing, Constitutional Union Party, National Union Party. Results show that the impact of the free banking laws on innovation remain positive and significant after controlling for the state-level political parties in power.

Overall, the results confirm the causality that greater access to finance brought by free banking spurred innovation.

6 The Role of Labor Scarcity

Our evidence so far shows a robust, positive effect of state-level free banking laws on innovation, which did not appear to be driven by pre-existing trends in innovation output prior to free banking or by omitted shocks coinciding with the free banking laws. In this section, we explore an important underlying economic channel that shaped how free banking laws affected innovation outcome: labor scarcity.

6.1 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. However, it is difficult to empirically test it in today's world because labor is mobile across regions. The antebellum period provides a unique laboratory in which to test the importance of labor scarcity. During this historical episode, free states and slave states coexisted. At the margin, slave labor in the South was less expensive than free labor in the north. In other words, the scarcity of labor in production was generally higher

[27] The Whig Party emerged in the 1830s as the leading opponent of Jacksonians, supporters of the policies of President Andrew Jackson (in office 1829–37) and his Democratic Party. It included former members of the National Republican and Anti-Masonic Parties. Along with the rival Democratic Party, it was central to the Second Party System from the early 1840s to the mid-1860s.

[28] The Tribune Almanac and Political Register kept a record of the name, party, year elected, and salary of the governor in each state since the establishment of the statehood.

in the free states. This historical setting provides us with a natural degree of heterogeneity in labor scarcity across regions.

Table 4 compares labor conditions and innovation conditions in the free states and slave states. Free states and slave states had similar levels of population, but the composition of the population was very different. Free states had a higher ratio of urban population to total population and a higher ratio of white people to the total population. By comparing labor cost—a direct measure of labor scarcity, we confirm that the free states faced a higher degree of labor scarcity compared to the slave states. Free states paid a higher daily average wage relative to slave states both for free labor with and without board. While the maintenance cost of slave labor to the owner would be trivial, we examine the daily hiring price which measures the opportunity cost of a slave laborer. We find that the daily hiring price for slave was only \$0.1 on average, much lower than that of a free labor.[29] Regarding innovation, free states produced more total patents, more industrial patents, and more agricultural patents relative to the slave states. The evidence is consistent with our conjecture that free states faced a higher degree of labor scarcity than the slave states, and free states had a higher level of innovation.

We are interested in whether and how being a free state or not affects the marginal impact of free banking laws on innovation. To this end, we estimate the following model:

$$\begin{aligned} Ln(Patents)_{i,t+s} =& \alpha + \beta_1 Free\ banking_{i,t} \times Free\ state_i + \beta_2 Free\ banking_{i,t} \\ &+ \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}, \end{aligned} \tag{7}$$

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 $Free\ banking_{i,t}$ and $Free\ state_i$.[30] 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 production of the free states posed a stronger incentive to innovate, we should expect β_1 to be positive and significant.

[29] The lower price of slave labor relative to free labor should not be perceived as an indication of lower productivity of slave labor. As argued by Fogel and Engerman (1974), the southern farms are more efficient than the northern factories. Olmstead and Rhode (2008, 2010) also show fast productivity growth in the antebellum cotton economy: The average daily cotton-picking rate increased about fourfold between 1801 and 1862.

[30] We do not include $Free\ state_i$ separately in the model. It is because $Free\ state_i$ would be collinear with state fixed effects, which makes the coefficient estimate on $Free\ state_i$ biased. Including $Free\ state_i$ in the model or not only affects coefficient estimates on state fixed effects, but not the other variables.

We report the results estimating Eq. (7) in Table 5. The coefficient estimates of *Free banking*$_{i,t}$ × *Free state*$_i$ are positive and significant at the 1% level. Based on the coefficient estimate reported in column (3), free states with free banking laws generated a total of 55.8% more patents than slave states with free banking in the third year following the law passage. Overall, these findings show 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.

6.2 Triple Difference-in-differences: Introducing Industry Classification

Free states and slave states differed in many dimensions in addition to labor scarcity conditions. Hence one potential concern is that we capture a factor that did not pertain to labor scarcity. To address this concern, we introduce patent industries in the analysis to control the comparison. Differences in labor scarcity across industries and states present a unique opportunity for us to pin down the labor scarcity channel. In particular, we make use of the differences in relative labor scarcity across free labor and slave labor in free states and slave states, respectively. In free states, the system of wage-earning free labor led to a scarcity in labor supply, especially in the fast-growing manufacturing industry. In slave states, labor was less scarce in general; importantly, there was relatively abundant slave labor that constituted the main work force of the agricultural industry. Therefore, we could rank the degree of labor scarcity within each state and industry bracket in the following ascending order: agricultural industry in slave states, manufacturing industry in slave states, agricultural industry in free states, and manufacturing industry in free states.

According to the rank of labor scarcity, we have the following conjectures: Upon free banking, (1) within slave states, the innovation could experience a decrease in the agricultural industry where labor was abundant; (2) within agricultural industry, 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 the manufacturing industry relative to agricultural industry; (4) the highest innovation increase was in manufacturing industry in the free states, where labor was most scarce. We test these above hypotheses by estimating a triple difference-in-differences (DDD) model as in Gruber (1994), Chetty, Looney, and Kroft (2009), and Akee, Copeland,

Costello, and Simeonova (2018).[31] The model is as follows:

$$\begin{aligned} Ln(Patents)_{i,j,t+s} =& \alpha + \beta_1 Free\ banking_{i,t} + \beta_2 Free\ banking_{i,t} \times Free\ state_i \\ &+ \beta_3 Free\ banking_{i,t} \times Manufacturing\ patent_j \\ &+ \beta_4 Free\ banking_{i,t} \times Free\ state_i \times Manufacturing\ patent_j \\ &+ \beta_5 Free\ state_i \times Manufacturing\ patent_j \\ &+ \beta_6 Manufacturing\ patent_j + \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,j,t}, \end{aligned} \tag{8}$$

where i indexes state, t indexes year, j indexes patent technology category, and s is equal 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 agricultural industry" DD 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" DD estimate of free banking on innovation, measuring the effects of free banking on manufacturing innovation (relative to agricultural innovation) in slave states. The DDD estimate β_4 measures the impact of free banking on manufacturing innovation (relative to agricultural innovation) in free states (relative to slave states). If our conjecture is correct, we should expect to see a negative β_1, a positive β_2, a positive β_3, and a positive β_4.

We report the regression results estimating Eq. (8) in Table 6. The coefficient estimate β_1 is indeed negative and significant at 1% significance level, suggesting that slave states experienced a drop in agricultural innovation following the passage of free banking. 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 1% 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 1% level, suggesting that the differential effects of the free banking laws on manufacturing innovation relative to agricultural innovation were higher in free states than in

[31] We do not use a difference-in-differences (DD) methodology because that would restrict the estimation to specific subsets of the data (either free states, slave states, agricultural industry, or manufacturing industry). The preferred specification in this setting, a triple difference, uses all available data and all possible sources of variation in the data (Akee, Copeland, Costello, and Simeonova, 2018). In particular, we compare outcomes across agricultural industry and manufacturing industry as well as across free states and slave states.

slave states.

The results are consistent with our conjectures. These results confirm that the free banking laws promoted innovation when labor was scarce, and further suggest that free banking discouraged innovation where labor was plentiful and the marginal cost of labor was low—in the agricultural industry of slave states.

6.3 Banking and Slavery in the South

The result that free banking discouraged agricultural innovation in slave states contains an important insight. It suggests that greater access to finance did not necessarily promote innovation. One possible explanation for the decline of agricultural patents is that access to finance further increased the slave labor 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 helped to underwrite the sale of slaves, using them as collateral and they were willing to sell slaves as part of foreclosure proceedings on anyone who failed to fulfill a debt contract.[32] While most of the direct historical records in early decades of the antebellum era concerned slave financing through traditionally-chartered banks (e.g. Murphy, 2017), the connectivity of the banking sector implies indirect relations between all southern banks and slavery.

An alternative explanation is that greater access to finance in a slave state might attract more slave holders and slaves to a state that passed the free banking laws (Fogel and Engerman, 1974). In both cases, free banking increased slave labor and further discouraged innovation. To verify the channel, we examine total changes in the slave population across states and find an increase in the slave population after free banking passage in Table 7.[33] Taken together, finance promotes innovation when labor is scarce and may impede innovation when labor becomes more abundant.

[32] See for example discussions in Stone (1915), Martin (2010), Depuydt (2013), Gonzalez, Marshall, and Naidu (2017).

[33] The census reports slave population per state decennially, hence the data in our regression are for the slave populations in 1810, 1820, 1830, 1840, 1850, and 1860.

6.4 Robustness: Controlling for Industry Concentration

One potential concern about the current results is that slave and free states were vastly different in economic conditions and industry composition, and these factors, rather than the difference in labor scarcity, could drive our results. We next conduct additional robustness tests to ensure that our results are not driven by the difference in industry concentration between free and slave states.

Table 8 reports results estimating Eq. (8) for the subsamples. Panel A imposes the restriction that the states included should have agricultural output less than manufacturing output. Slave states included in the restricted sample include Delaware, Maryland, and District of Columbia. The results are qualitatively similar to those in Table 6. The coefficient estimates on *Free banking*$_{i,t}$ and other variables are dropped due to a lower power of the tests with fewer state observations. The coefficient estimate on *Free banking*$_{i,t} \times$ *Free state*$_{i,t} \times$ *Manufacturing patent*$_j$ is positive and significant. Again, this confirms that the impact of access to finance on innovation was most pronounced where labor was most scarce.

Panel B imposes the restriction that the states included should have agricultural output higher than manufacturing output. This restriction selects states where agriculture was the dominating industry. Free states included in the restricted sample include Illinois, Indiana, and Vermont. Once again, the results are qualitatively similar to those in Table 6. The coefficient estimates on *Free banking*$_{i,t}$ are still negative and significant, suggesting that the negative impact of free banking laws on agricultural innovation in slave states prevails. While the coefficient estimates on *Free banking*$_{i,t} \times$ *Free state*$_{i,t} \times$ *Manufacturing patent*$_j$ become insignificant because there are fewer observations, they remain economically sizable.

7 Extensions and Robustness

7.1 Free banking and Access to Finance

Earlier in the historical background, we have argued that the passage of the free banking laws accelerated bank entry, expanded the customer base of banks, and encouraged small businesses. In this section, we document the direct impact of free banking on access to finance. We hypothesize that passage of free banking laws increased access to finance and therefore encouraged

innovation by increasing the credit supply needed to conduct innovation.

We estimate the following model:

$$Finance_{i,t} = \alpha + \beta Free\ banking_{i,t} + \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}, \tag{9}$$

where $Finance_{i,t}$ is a measure of access to finance at state i in year t. We use the counts of free banks, the ratio of free bank counts to total bank counts, the amount of loans issued by free banks, and the ratio of loan amounts from free banks to loan amounts from all banks. Table 9 reports the results estimating Eq. (9). As shown in the table, there was a significant increase in free bank counts and loans, in both the magnitude and the ratio. The economic magnitude is also sizable. The passage of the free banking laws led to a 10.4 (=1.129 $\times$ 3.04) increase of free bank counts and a \$9 (=6.915 $\times$ 1.3) million increase of free bank loans in the third year following the passage. The increase in the free bank counts accounted for 53.4% (=10.4/19.49) of the state-level free bank count variability, and the increase in the free bank loans accounted for 69.2% (=9 million/13 million) of the state-level free bank loan variability. The evidence is consistent with the hypothesis that the passage of free banking laws improved access to finance.

7.2 Free Banking in the Slave States

We have shown that free banking contributed in reshaping the direction of innovation in the slave states, owing to the relative abundance of slave labor in agriculture and the relative scarcity of labor in manufacturing. However, historical research also pointed out that the southern banks functioned quite differently compared with banks in the North (e.g. Calomiris and Schweikart, 1991; Schweikart, 1987a,b).[34] Admittedly, due to the pre-existing branch bank networks serving plantation owners, entry of free banks was quite limited in the Southern states. Among all the southern states that passed the law, free banking was most active in Louisiana.

To mitigate the concern about limited free banking in the South, we next conduct tests by focusing on only slave states. We examine the impact of free banking on access to finance in the slave states by estimating Eq. (9), and the impact of free banking on innovation in the slave states by estimating Eq. (5). The estimation results are shown in Table 10. The effect of free banking on bank counts, bank loans, and innovation remains statistically and economically

[34] Southern banks refer to banks in the southern states, i.e. the slave states in our context.

significant. We argue that, while the number of free bank entry might be endogenous to other state-level factors for example the existing banking system, the specific passage year of the law captured well exogenous changes in access to finance.

8 Conclusion

In this paper, we establish labor scarcity as a novel and important economic channel for the finance–growth nexus. We take a historical approach and examine antebellum America from 1812 to 1860. This period witnessed the staggered passage of free banking laws across eighteen states, which provides us with a unique setting to identify banking shocks. Furthermore, the sharp contrast in labor scarcity between slave and free states makes antebellum America a perfect setting in which to examine the labor scarcity channel.

We confirm that access to finance, as identified by the staggered passage of the 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. 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 research sheds new light on the factors that drive innovation.

Appendix

A 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

B Variable Definitions

Variable	Definition
Innovation Measure	
Ln(Patents)	Natural logarithm of one plus a state's total number of patents granted in a given year.
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 value of the variable reverts to zero in and after 1840, and before 1857.
$Before^{1^-}$	A variable that takes the value of one all years up to and including one year prior to the free banking law and zero otherwise.
$After^{3^+}$	A variable that takes the value of one, in year three and beyond after free banking and zero otherwise.
$After^{2}$	A variable that takes the value of one, in year two after the passage of free banking law and zero otherwise.
$After^{1}$	A variable that takes the value of one, in the year following the passage of free banking law 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.
Slave ratio	Ratio of slave 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 in a given year.
Manufacturing patent	A variable that takes the value of one if the patent counts in a state restrict to the manufacturing industry and zero if the patent counts in a state restrict to the agricultural industry (see section 4.1 for details on industry classification of patents).
Max rate	The maximum interest rate limit in a state imposed by usury laws.
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.
Daily average wage (with board)	Average daily wage with board at the state level weighted by the proportion of free labor in the state.
Daily average wage (without board)	Average daily wage without board at the state level weighted by the proportion of free labor in the state.

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Table 1
Summary statistics.
This table gives an overview of this paper's sample. Panel A reports summary statistics for the state-year observations, including dependent, independent, and control variables. Panel B reports the passage year of free banking laws in each affected state. Definitions of the variables are in Appendix B.

Panel A: Summary statistics

	P25	P50	Mean	P75	SD	N
Patents	1	5	25.14	18	75.40	1,491
Patents (agricultural)	0	0	2.27	2	7.2	1,491
Patents (manufacturing)	0	1	10.19	6	35.03	1,491
Population (thousands)	270	780	1,100	1,400	1,200	1,491
Urban ratio	0.02	0.05	0.12	0.16	0.18	1,491
Slave ratio	0	0	0.15	0.31	0.19	1,491
White ratio	0.65	0.93	0.82	0.99	0.19	1,491
Political party	0	0	0.38	1	0.48	868
Max rate	0.06	0.06	0.08	0.08	0.07	1,419
Free bank counts	0	0	3.04	0	19.49	1,491
Free ratio	0	0	0.03	0	0.14	1,491
Free bank loans (thousands)	0	0	1,300	0	13,000	1,491
Free bank loan ratio	0	0	0.03	0	0.15	1,491

Panel B: Passage of free banking laws

State	Year of passage	Bank entry 3 years after FBL[b]	Total bank entry after FBL	
			Free	Charter
Michigan	1837, 1857[a]	40 (na)	40	7
New York	1838	82 (84%)	418	0
Georgia	1838	3 (8%)	2	17
Alabama	1849	2 (100%)	2	10
New Jersey	1850	23 (88%)	29	16
Vermont	1851	6 (29%)	4	17
Ohio	1851	38 (475%)	69	0
Massachusetts	1851	18 (14%)	7	49
Illinois	1851	31 (na)	141	0
Connecticut	1852	16 (36%)	14	26
Indiana	1852	93 (664%)	104	0
Wisconsin	1852	43 (na)	140	0
Tennessee	1852	16 (73%)	22	15
Louisiana	1853	3 (16%)	5	0
Florida	1853	0 (0%)	0	2
Minnesota	1858	16 (na)	16	0
Iowa	1858	13 (na)	0	13
Pennsylvania	1860	6 (11%)	0	47

[a] Michigan passed the free banking law in 1837, abolished in 1840, and reinstated in 1857. The passage years are from Rockoff (1974).
[b] The percentage is taken over the banks operating prior to years of entry. Statistics for bank entry data comes from Economopoulous and O'Neill (1995).

Table 2
Baseline regressions.
This table reports OLS regression estimates of Eq. (5). The dependent variable in columns 1–2, 3–4, and 5–6 is the natural logarithm of one plus the sum of the patents granted in a state in year t+1, t+2, and t+3, respectively. Definitions of variables are in Appendix B. Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

	Ln(Patents)					
	t+1		t+2		t+3	
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	0.440***	0.385***	0.518***	0.456***	0.531***	0.463***
	(0.081)	(0.064)	(0.104)	(0.081)	(0.111)	(0.085)
Ln(Population)		0.452***		0.517***		0.587***
		(0.044)		(0.055)		(0.063)
Urban ratio		1.493***		2.239***		2.877***
		(0.482)		(0.815)		(0.906)
Slave ratio		-2.924*		-4.504**		-5.955***
		(1.499)		(1.911)		(2.180)
White ratio		-0.944		-2.154		-3.022
		(1.391)		(1.734)		(1.834)
Constant	0.033	-3.925***	0.084	-3.321**	-0.070	-3.234**
	(0.089)	(1.180)	(0.098)	(1.344)	(0.107)	(1.404)
Observations	1,491	1,491	1,491	1,491	1,491	1,491
R-squared	0.878	0.893	0.868	0.889	0.861	0.888
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 3
Additional endogeneity tests.
This table reports robustness tests of the baseline regressions. Panel A reports OLS regression estimates of Eq. (6) with Michigan state excluded. Since Michigan abolished the free banking law once and reinstated later, the dynamic effects of the free banking laws on innovation might be different from other states. Dependent variables in columns 1–2 are the natural logarithm of one plus the sum of the patents granted in year t+1. Panel B reports OLS regression estimates of Eq. (5) with randomized free banking passage across states. Dependent variables in columns 1-3 are the natural logarithm of one plus the sum of the patents granted in year t+1, t+2, and t+3, respectively. Panel C reports OLS regression estimates of Eq. (5) with additional controls. Columns 1-3 have *Max rate* as the additional control variable. Dependent variables in columns 1-3 are the natural logarithm of one plus the sum of the patents granted in year t+1, t+2, and t+3, respectively. Columns 4-6 have *Political party* as the additional control variable. Dependent variables in columns 4-6 are the natural logarithm of one plus the sum of the patents granted in year t+1, t+2, and t+3, respectively. Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of variables are in Appendix B.

Panel A: Dynamic effects of free banking on innovation

	Ln(Patents)	
	(1)	(2)
$Before^{1-}$	-0.207	-0.082
	(0.172)	(0.149)
$After^{1}$	0.283***	0.273**
	(0.104)	(0.106)
$After^{2}$	0.230*	0.226*
	(0.138)	(0.137)
$After^{3+}$	0.310***	0.405***
	(0.153)	(0.137)
Ln(Population)		0.512***
		(0.102)
Urban ratio		1.374*
		(0.799)
Slave ratio		-1.709
		(4.031)
White ratio		-0.991
		(4.487)
Constant	0.239	-6.295
	(0.187)	(3.857)
Observations	1,442	1,442
R-squared	0.880	0.895
State FE	Yes	Yes
Year FE	Yes	Yes

Panel B: Randomization of free banking

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking	0.061	0.004	0.006
	(0.060)	(0.057)	(0.057)
Ln(Population)	0.467***	0.531***	0.600***
	(0.047)	(0.059)	(0.070)
Urban ratio	1.646***	2.451***	3.091***
	(0.519)	(0.878)	(0.971)
Slave ratio	-1.892	-3.180*	-4.612**
	(1.377)	(1.748)	(2.042)
White ratio	-0.163	-1.203	-2.056
	(1.353)	(1.693)	(1.814)
Constant	-4.934***	-4.514***	-4.446***
	(1.132)	(1.269)	(1.326)
Observations	1,491	1,491	1,491
R-squared	0.890	0.885	0.883
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Panel C: Are other factors driving the results?

	Ln(Patents)					
	t+1	t+2	t+3	t+1	t+2	t+3
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	0.368***	0.431***	0.441***	0.228***	0.327***	0.350***
	(0.067)	(0.083)	(0.087)	(0.056)	(0.086)	(0.095)
Max rate	0.397	0.016	-0.152			
	(0.249)	(0.498)	(0.324)			
Political party				0.022	0.082	0.126**
				(0.051)	(0.061)	(0.058)
Ln(Population)	0.593***	0.652***	0.732***	0.503***	0.559***	0.618***
	(0.051)	(0.062)	(0.069)	(0.108)	(0.103)	(0.115)
Urban ratio	1.905***	2.654***	3.202***	1.343	2.689*	3.375**
	(0.498)	(0.848)	(0.917)	(0.840)	(1.335)	(1.489)
Slave ratio	-4.767**	-5.719**	-6.272***	-5.402**	-9.074**	-12.687***
	(1.832)	(2.144)	(2.054)	(2.605)	(3.317)	(3.869)
White ratio	-2.469	-2.957	-2.642	-5.110**	-7.805***	-9.832***
	(1.837)	(2.043)	(1.737)	(2.097)	(2.471)	(2.231)
Constant	-4.129**	-4.070**	-5.253***	-0.242	1.995	3.521
	(1.648)	(1.708)	(1.492)	(2.792)	(2.739)	(2.133)
Observations	1,419	1,419	1,419	868	868	868
R-squared	0.897	0.891	0.888	0.918	0.913	0.912
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 4
Differences in labor conditions: Slave states vs. free states.
This table presents summary statistics for labor in slave states and free states. Definitions of variables are in Appendix B.

	P25	P50	Mean	P75	SD	N
Free states						
Population (thousands)	420	650	1,300	1,500	1,400	743
Urban ratio	0.03	0.09	0.13	0.17	0.14	743
Slave ratio	0	0	0	0	0	743
White ratio	0.97	0.99	0.98	1	0.02	743
Daily average wage (without board)	0.63	0.69	0.78	0.76	0.46	743
Daily average wage (with board)	0.88	0.940	1.050	1	0.58	743
Total patents	3	11	44.01	42	102.9	743
Manufacturing patents	0	3	18.21	14	48.11	743
Agricultural patents	0	0	3.81	3	9.8	743
Slave states						
Population (thousands)	190	900	950	1,400	740	748
Urban ratio	0.01	0.04	0.12	0.11	0.22	748
Slave ratio	0.18	0.31	0.3	0.44	0.16	748
White ratio	0.55	0.65	0.66	0.76	0.14	748
Daily average wage (without board)	0.49	0.52	0.57	0.66	0.14	748
Daily average wage (with board)	0.69	0.75	0.81	0.95	0.22	748
Daily slave hire price	0.05	0.08	0.10	0.13	0.08	196
Slave sale price	1.79	3.13	3.61	4.91	3.71	294
Total patents	0.5	3	6.39	7	10.87	748
Manufacturing patents	0	0	2.23	2	4.61	748
Agricultural patents	0	0	0.75	1	1.86	748

Table 5
Labor scarcity and innovation.
This table presents regression coefficient estimates of Eq. (7). Dependent variables in columns 1–3 are the natural logarithm of one plus the sum of the patents granted in year t+1, t+2, and t+3, respectively. Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of variables are in Appendix B.

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking × *Free state*	0.442***	0.469***	0.558***
	(0.084)	(0.148)	(0.172)
Free banking	0.092	0.146	0.094
	(0.090)	(0.087)	(0.095)
Ln(Population)	0.434***	0.498***	0.564***
	(0.043)	(0.050)	(0.057)
Urban ratio	0.873*	1.581**	2.093***
	(0.469)	(0.670)	(0.714)
Slave ratio	-2.124	-3.655**	-4.945**
	(1.458)	(1.723)	(1.858)
White ratio	-0.154	-1.315	-2.024
	(1.389)	(1.612)	(1.537)
Constant	-4.421***	-3.847***	-3.860***
	(1.213)	(1.315)	(1.261)
Observations	1,491	1,491	1,491
R-squared	0.894	0.891	0.890
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Table 6
Labor scarcity and innovation: Patent industry classification.
This table presents regression coefficient estimates of Eq. (8). Dependent variables in columns 1–3 are the natural logarithm of one plus the sum of the patents granted in year t+1, t+2, and t+3, respectively. Controls include *Ln(Population)*, *Urban ratio*, *Slave ratio*, and *White ratio*. Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of variables are in Appendix B.

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking	-0.298***	-0.232**	-0.244**
	(0.100)	(0.098)	(0.094)
Free banking × *Free state*	0.789***	0.831***	0.905***
	(0.125)	(0.138)	(0.134)
Free banking × *Manufacturing patent*	0.248**	0.220**	0.249**
	(0.104)	(0.108)	(0.108)
Free banking × *Free state* × *Manufacturing patent*	0.345**	0.355***	0.306**
	(0.129)	(0.128)	(0.115)
Manufacturing patent × *Free state*	0.409***	0.428***	0.453***
	(0.039)	(0.040)	(0.040)
Manufacturing patent	0.337***	0.352***	0.364***
	(0.040)	(0.040)	(0.040)
Constant	-0.048	0.611	0.757
	(0.832)	(0.875)	(0.855)
Controls	Yes	Yes	Yes
Observations	2,982	2,982	2,982
R-squared	0.789	0.791	0.795
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Table 7
Slave population.
This table presents OLS regression coefficient estimates of regressing *Slave ratio* on *Free banking*. *Slave ratio* is the proportion of slaves out of total population (multiplied by 100). Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of variables are in Appendix B.

	Slave ratio	
	(1)	(2)
Free banking	1.090*	0.751**
	(0.470)	(0.217)
Ln(Population)		0.273
		(0.232)
Urban ratio		-2.827
		(2.660)
White ratio		-77.427***
		(14.425)
Constant	40.244***	82.519***
	(2.657)	(6.977)
Controls	No	Yes
Observations	160	160
R-squared	0.986	0.996
State FE	Yes	Yes
Year FE	Yes	Yes

Table 8
Labor scarcity and innovation: Controlling for industry concentration.
This table presents OLS regression coefficient estimates. Panel A restricts the sample to states with more manufacturing output, i.e., states with more annual manufacturing output than annual agricultural output. Panel B restricts the sample to states with more agricultural output, i.e., states with more annual agricultural output than annual manufacturing output. Dependent variables in columns 1–3 are the natural logarithm of one plus the sum of the patents granted in year t+1, t+2, and t+3, respectively. Controls include *Ln(Population)*, *Urban ratio*, *Slave ratio*, and *White ratio*. Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of variables are in Appendix B.

Panel A: States with more manufacturing output

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking × *Free state*	0.179**	0.272***	0.260***
	(0.085)	(0.069)	(0.067)
Free banking × *Free state* × *Manufacturing patent*	0.844***	0.781***	0.783***
	(0.099)	(0.093)	(0.101)
Manufacturing patent × *Free state*	0.320***	0.350***	0.373***
	(0.070)	(0.071)	(0.072)
Manufacturing patent	0.668***	0.682***	0.696***
	(0.080)	(0.080)	(0.079)
Constant	-17.251***	-16.430***	-17.068***
	(4.034)	(4.273)	(4.068)
Controls	Yes	Yes	Yes
Observations	1,146	1,146	1,146
R-squared	0.847	0.851	0.854
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Panel B: States with more agricultural output

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking	-0.340***	-0.242**	-0.226**
	(0.101)	(0.102)	(0.096)
Free banking × *Free state*	0.814***	0.834***	0.966***
	(0.118)	(0.144)	(0.147)
Free banking × *Manufacturing patent*	0.339***	0.310***	0.340***
	(0.105)	(0.108)	(0.109)
Free banking × *Free state* × *Manufacturing patent*	0.149	0.205	0.135
	(0.134)	(0.143)	(0.134)
Manufacturing patent × *Free state*	0.153***	0.158***	0.184***
	(0.038)	(0.039)	(0.039)
Manufacturing patent	0.246***	0.262***	0.273***
	(0.035)	(0.035)	(0.036)
Constant	1.565	3.601	5.617***
	(2.095)	(2.207)	(2.045)
Controls	Yes	Yes	Yes
Observations	1,836	1,836	1,836
R-squared	0.750	0.749	0.755
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Table 9

Free banking and access to finance.

This table presents OLS regression coefficient estimates for Eq. (9). Panel A examines free banks. Dependent variables in columns 1–3 are the natural logarithm of one plus free bank counts at a state in year t+1, t+2, t+3, respectively. Dependent variables in columns 4–6 are the ratio of free bank counts and total bank counts at a state in year t+1, t+2, t+3. Panel B examines loans lent by free banks. Dependent variables in columns 1-3 are the natural logarithm of one plus free bank loans at a state in year t+1, t+2, and t+3, respectively. Dependent variables in columns 4-6 are the ratio of free bank loans and total bank loans at a state in year t+1, t+2, and t+3, respectively. Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of variables are in Appendix B.

Panel A: Free banks

	Ln(Free bank counts)			Free bank ratio		
	t+1	t+2	t+3	t+1	t+2	t+3
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	1.531***	1.326***	1.129***	0.232***	0.189***	0.151***
	(0.144)	(0.190)	(0.216)	(0.027)	(0.033)	(0.036)
Ln(Population)	0.126***	0.138***	0.145***	0.053***	0.054***	0.053***
	(0.039)	(0.045)	(0.050)	(0.012)	(0.014)	(0.015)
Urban ratio	3.312***	2.870***	2.408***	0.421***	0.381***	0.335***
	(0.692)	(0.799)	(0.838)	(0.086)	(0.099)	(0.105)
Slave ratio	-3.541***	-3.897***	-3.924***	-0.959***	-0.974***	-0.931***
	(1.313)	(1.139)	(1.061)	(0.286)	(0.248)	(0.229)
White ratio	-3.752**	-4.059***	-3.982***	-0.836***	-0.877***	-0.844***
	(1.450)	(1.236)	(1.159)	(0.298)	(0.243)	(0.220)
Constant	1.832	2.022**	1.904**	0.184	0.217	0.193
	(1.145)	(0.959)	(0.830)	(0.225)	(0.182)	(0.150)
Observations	1,491	1,491	1,491	1,491	1,491	1,491
R-squared	0.626	0.573	0.530	0.537	0.484	0.444
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by Year	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Free bank loans

	Ln(Free bank loans)			Free bank loan ratio		
	t+1	t+2	t+3	t+1	t+2	t+3
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	7.486***	7.229***	6.915***	0.187***	0.176***	0.160***
	(0.613)	(0.590)	(0.770)	(0.015)	(0.018)	(0.028)
Ln(Population)	0.510***	0.651***	0.825***	0.073***	0.078***	0.084***
	(0.148)	(0.161)	(0.175)	(0.009)	(0.010)	(0.011)
Urban ratio	13.088***	13.477***	14.133***	0.430***	0.453***	0.484***
	(3.402)	(3.683)	(3.824)	(0.079)	(0.083)	(0.079)
Slave ratio	-9.392	-12.445	-15.819**	-0.692***	-0.779***	-0.879***
	(7.522)	(7.533)	(7.072)	(0.231)	(0.235)	(0.230)
White ratio	-13.925	-18.122*	-22.842**	-0.308	-0.407	-0.527**
	(10.247)	(10.280)	(9.081)	(0.265)	(0.277)	(0.252)
Constant	5.796	7.837	9.924	-0.509**	-0.479*	-0.441*
	(9.494)	(9.338)	(8.262)	(0.226)	(0.250)	(0.236)
Observations	1,452	1,413	1,374	1,452	1,413	1,374
R-squared	0.586	0.563	0.539	0.487	0.482	0.477
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Table 10

Free banking in the slave states.

This table presents OLS regression coefficient estimates for Eq. (9) with only slave states. Panel A examines free banks. Dependent variables in columns 1-3 are the natural logarithm of one plus free bank counts at a state in year t+1, t+2, t+3, respectively. Dependent variables in columns 4-6 are the ratio of free bank counts and total bank counts at a state in year t+1, t+2, t+3. Panel B examines loans lent by free banks. Dependent variables in columns 1–3 are the natural logarithm of one plus free bank loans at a state in year t+1, t+2, and t+3, respectively. Dependent variables in columns 4–6 are the ratio of free bank loans and total bank loans at a state in year t+1, t+2, and t+3, respectively. Panel C examines innovation. The dependent variable in columns 1, 2, and 3 is the natural logarithm of one plus the sum of the patents granted in a state in year t+1, t+2, and t+3, respectively. Robust standard errors clustered at the year level are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of variables are in Appendix B.

Panel A: Free banks

	Ln(Free bank counts)			Free bank ratio		
	t+1	t+2	t+3	t+1	t+2	t+3
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	0.235***	0.209***	0.183***	0.038***	0.033***	0.031***
	(0.045)	(0.047)	(0.048)	(0.009)	(0.007)	(0.007)
Ln(Population)	-0.035***	-0.030***	-0.026***	-0.004***	-0.003**	-0.003**
	(0.010)	a(0.010)	(0.009)	(0.001)	(0.001)	(0.001)
Urban ratio	0.638***	0.627***	0.587***	0.124***	0.126***	0.122***
	(0.165)	(0.140)	(0.133)	(0.034)	(0.027)	(0.026)
Slave ratio	-0.807**	-0.787***	-0.691***	-0.151***	-0.143***	-0.124***
	(0.329)	(0.277)	(0.254)	(0.054)	(0.035)	(0.032)
White ratio	-2.084***	-2.034***	-1.883***	-0.367***	-0.357***	-0.328***
	(0.577)	(0.493)	(0.461)	(0.099)	(0.074)	(0.071)
Constant	2.111***	2.015***	1.841***	0.355***	0.338***	0.307***
	(0.573)	(0.501)	(0.465)	(0.094)	(0.071)	(0.068)
Observations	748	748	748	748	748	748
R-squared	0.454	0.421	0.389	0.426	0.394	0.378
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Free bank loans

	Ln(Free bank loans)			Free bank loan ratio		
	t+1	t+2	t+3	t+1	t+2	t+3
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	2.894***	2.924***	2.947***	0.007***	0.008***	0.009***
	(0.691)	(0.698)	(0.702)	(0.002)	(0.002)	(0.002)
Ln(Population)	-0.332***	-0.319***	-0.300**	-0.001***	-0.000***	-0.000**
	(0.112)	(0.112)	(0.114)	(0.000)	(0.000)	(0.000)
Urban ratio	8.193***	8.840***	9.761***	0.025***	0.029***	0.033***
	(2.683)	(2.642)	(2.257)	(0.008)	(0.009)	(0.008)
Slave ratio	-10.585**	-11.373**	-12.154***	-0.030**	-0.035**	-0.039***
	(4.821)	(4.622)	(3.824)	(0.014)	(0.014)	(0.012)
White ratio	-26.118***	-28.402***	-30.940***	-0.073***	-0.082***	-0.092***
	(8.964)	(8.718)	(7.419)	(0.025)	(0.026)	(0.024)
Constant	25.699***	27.322***	29.035***	0.070***	0.077***	0.084***
	(8.679)	(8.377)	(7.249)	(0.024)	(0.024)	(0.023)
Observations	730	712	694	730	712	694
R-squared	0.402	0.403	0.404	0.334	0.357	0.376
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel C: Innovation

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking	0.191**	0.270***	0.247***
	(0.090)	(0.083)	(0.083)
Ln(Population)	0.315***	0.412***	0.516***
	(0.064)	(0.086)	(0.102)
Urban ratio	0.805	1.418	2.326
	(1.167)	(1.492)	(1.414)
Slave ratio	4.114**	2.043	-0.208
	(1.553)	(1.949)	(2.086)
White ratio	6.590***	5.135***	3.423*
	(1.711)	(1.897)	(1.944)
Constant	-9.367***	-8.850***	-8.371***
	(1.562)	(1.520)	(1.540)
Observations	748	748	748
R-squared	0.810	0.802	0.795
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes