Institutional Innovation and the Adoption of New Technologies: The Case of Steam

Thor Berger and Vinzent Ostermeyer

This paper documents how the advent of the limited liability corporation contributed to the diffusion of steam technology during Sweden's industrialization. Using longitudinal establishment-level data, we show that incorporation sharply raised the probability that industrial establishments adopted steam. Incorporation facilitated technology adoption partly by enabling smaller establishments to expand to a greater scale, where the use of steam became feasible. These results highlight that low barriers to incorporation may be an important lever for facilitating the diffusion of new technologies.

New technologies are a key driver of economic growth, but often diffuse at a remarkably slow pace.[1] The paradigmatic technology of the Industrial Revolution—steam power—is a case in point. Adopting

The Journal of Economic History, Vol. 85, No. 3 (September 2025). doi: 10.1017/ 10.1017/ S0022050725100855

Thor Berger is Pro Futura Scientia Fellow XVI, Swedish Collegium for Advanced Study (SCAS), Uppsala University; Associate Professor, Department of Economic History & Centre for Economic Demography, School of Economics and Management, Lund University; Research Affiliate, Centre for Economic Policy Research (CEPR); and Affiliated Researcher, Research Institute of Industrial Economics (IFN). E-mail: thor.berger@ekh.lu.se (corresponding author). Vinzent Ostermeyer is Researcher, Department of Economic History, School of Economics and Management, Lund University. E-mail: vinzent.ostermeyer@ekh.lu.se.

We thank Bishnupriya Gupta (the editor), three anonymous referees, Fredrik N G Andersson, Sebastian Braun, Olof Ejermo, Chris Colvin, Ben Gales, Astrid Kander, Markus Lampe, Steven Nafziger, Robert A. Margo, Mats Olsson, Svante Prado, Richard Unger, and Jaco Zuijderduijn as well as seminar participants at Bayreuth University, Lund University, the 14th Swedish Economic History Meeting (Gothenburg University), the 2021 FRESH Meeting (Lund University), the 2022 Datini-ESTER Advanced Seminar (Prato), the 2022 World Economic History Congress (Paris), the 5th German Congress for Economic and Social History (Leipzig), and the Research Institute of Industrial Economics (IFN, Stockholm) for valuable comments and discussions. We thank Ingvild Almås, Timo Boppart, Konrad Burchardi, and Hannes Malmberg for sharing the data of the Swedish Incorporation Registers with us. Funding from the Department of Economic History at Lund University, the Swedish Research Council, Jan Wallanders och Tom Hedelius stiftelse, Riksbankens Jubileumsfond, and Stiftelsen för främjande av ekonomisk forskning vid Lunds Universitet is gratefully acknowledged.

[1] A large literature documents that new technologies often diffuse at a slow pace (e.g., Mansfield 1961; Rosenberg 1972; Hall and Khan 2003; Hall 2004). In particular, economic historians have examined the slow diffusion of general-purpose technologies such as steam (Crafts 2004), as well as electricity and the personal computer (David 1990). More broadly, Comin and Hobijn (2010) use data from the past two centuries on the diffusion of 15 major technologies—among others: cars, electricity, railways, steamships, and telephones—across 166 countries to document an average adoption lag of almost half a century.

steam substantially raised productivity (Atack, Margo, and Rhode 2019, 2022), yet it diffused slowly, and its aggregate growth impacts took more than a century to fully materialize (Crafts 2004). Adoption involved major capital investments and often required firms to operate at a greater size than before (Atack, Bateman, and Margo 2008). Thus, a potential barrier to diffusion was that most industrial establishments during the early stages of industrialization were too small to profitably adopt the new technology.

Our paper uses establishment-level data covering Sweden's industrial take-off in the late nineteenth century to show that an institutional innovation—the limited liability corporation—contributed to the diffusion of steam technology, partly by enabling firms to expand the scale of their operations.

Limited liability was codified into law in most European nations around the mid-nineteenth century. In Sweden, the Companies Act of 1848 introduced the modern corporate form, which evolved into a liberal system of general incorporation by the 1860s. By granting owners limited liability, the corporate form may have facilitated the adoption of steam by lowering risks involved in making major capital investments as well as improving access to debt and equity markets.

To study the link between incorporation and adoption of steam, we use newly digitized data that allow us to track the organizational form and technology use of about 9,000 Swedish industrial establishments between 1864 and 1890. By the mid-nineteenth century, Sweden lagged far behind the industrial leaders, and few establishments relied on steam power. Larger establishments had a cost advantage in using steam power, yet the median industrial establishment employed about five workers—far too small to use steam. However, Sweden underwent a rapid industrial take-off in the 1870s, becoming one of the fastest-growing economies in Western Europe. Notably, the industrial breakthrough involved a widespread diffusion of steam technology, which became the most common power source among manufacturing firms within a decade.

Our analysis shows that the spread of steam technology was deeply intertwined with the rise of the modern corporation. We first document that corporations were more than three times as likely to have adopted steam compared to establishments owned by partnerships or sole proprietorships. OLS regressions show that incorporated establishments were significantly more likely to use steam also when flexibly controlling for industry and regional characteristics. A higher use of steam power among corporations is also evident conditional on establishment size and

location in an urban area, that is, factors that are highly correlated with both incorporation and the use of steam technology.[2] However, the cross-sectional association captures both a potential causal effect of incorporation as well as underlying factors that may have determined selection into incorporation.

To identify the impact of incorporation on the adoption of steam, we use the fact that hundreds of establishments converted to the corporate form. We examine these conversions in a difference-in-differences framework, comparing relative changes in the adoption of steam among establishments that convert to corporate form relative to those that remain organized as partnerships or sole proprietorships. The probability that an establishment adopts steam increases sharply in the years after incorporation. While these estimates control for time-invariant differences across establishments, there may still be either positive or negative selection into incorporation due to time-varying factors. However, we show that the results are similar when directly controlling for pre-existing differences in size or allowing establishments to follow different growth trends. The same conclusion holds when drawing on recent advances in the event-study literature and solely relying on the *timing* of incorporation among the subset of establishments that, at some point, incorporated (Sant'Anna and Zhao 2020; Callaway and Sant'Anna 2021).

We lastly show that Sweden's low barriers to incorporation facilitated the adoption of steam partly by enabling smaller firms to expand their operations to a size where it became feasible to adopt steam technology. Examining the heterogeneous impacts of incorporation, we find that the link between incorporation and steam adoption is mainly driven by initially smaller establishments, often located in rural areas with less developed capital markets. Typically, these establishments were too small to reap the rewards of steam prior to incorporation. However, after incorporation, they approximately doubled their workforce, reaching a scale required to adopt steam. To further bolster this interpretation, we draw on case study evidence underlining that smaller firms often actively used incorporation to simultaneously expand their operations and invest in steam, which was facilitated both by establishing

[2] An often-invoked virtue of the steam engine is that it reduced the locational constraints imposed by water power (Rosenberg and Trajtenberg 2004). However, Kim (2005) uses establishment-level data from the U.S. Census of Manufactures, showing that while workers in steam-using establishments were more likely to be found in urban areas, the shift from artisan shops to the large factory was the most important contributor to urbanization in the latter half of the nineteenth century. Consistent with these findings, we find that establishments located in urban areas were more likely to rely on steam, though this is partly accounted for by the larger size of establishments in cities.

limited liability among firm owners and improved access to long-term financing.

Our paper provides micro-level evidence of the corporation's role in accounting for the spread of steam technology during the nineteenth century. Thus, we advance the literature that studies the diffusion of steam, which has mainly relied on regionally aggregated data where firm-level determinants—such as organizational form—cannot be identified (e.g., Atack, Bateman, and Weiss 1980; Nuvolari, Verspagen, and von Tunzelmann 2011; Gutberlet 2014; Bogart et al. 2017; de Pleijt, Nuvolari, and Weisdorf 2020; Franck and Galor 2022; Ridolfi, Salvo, and Weisdorf 2022).[3] A seminal exception is Atack, Bateman, and Margo (2008), who use cross-sectional establishment-level data from the U.S. Census of Manufactures, documenting that the use of steam technology is associated with greater establishment size.[4] We leverage the longitudinal nature of our data to contribute complementary evidence that firms actively used incorporation to achieve greater scale, which arguably was central in enabling many initially small firms to adopt steam.

Our findings also contribute to a contentious literature on the role of the modern corporation in accounting for late nineteenth-century growth (e.g., Landes 1966; Chandler 1977; Rosenberg and Birdzell, Jr. 1986). Due to the scarcity of data, few studies have been able to identify how incorporation affected firm-level outcomes, and most of the recent literature has still relied on country- or industry-level data (e.g., Guinnane et al. 2007; Foreman-Peck and Hannah 2015; Hilt 2015).[5] Gregg and Nafziger (2019) and Gregg (2020) are important recent exceptions, with the latter showing that incorporation among Russian factories led to increases in labor productivity and aggregate machine power. However, Russia lacked

[3] Coal looms large in the literature on the regional diffusion of steam, which is reflected in the fact that steam technology was often most intensively adopted in areas proximate to coal deposits (see, e.g., Crafts and Mulatu 2006; Nuvolari, Verspagen, and von Tunzelmann 2011; Fernihough and O'Rourke 2021). We provide evidence from a country that, in contrast to the early industrializers, virtually lacked coal reserves. The fact that the limited liability corporation facilitated the diffusion of steam technology in a country that lacked coal broadly aligns with a revisionist literature arguing that proximity to coal became increasingly irrelevant as transport costs fell over the nineteenth century (Clark and Jacks 2007).

[4] Also see Kim (2005). Recent contributions by Atack, Margo, and Rhode (2019, 2022) use uniquely detailed data from the *Hand and Machine Labor study* carried out in the 1890s by the U.S. Department of Labor, showing that the adoption of steam can account for a large fraction of the productivity increase associated with the transition to machine labor.

[5] Hilt (2006) is an exception, showing that the corporate form negatively affected the productivity in the American whaling industry by exacerbating oversight problems. Yet, whaling is a specific industry where expeditions can take years, making it impossible for shareholders to monitor the success or failure of the missions. Such oversight problems are arguably less pronounced in most other industries, where the corporation can function as a vehicle to attract capital.

a general incorporation law and required firms to undergo a costly process to incorporate. In contrast, Sweden had introduced a general incorporation system by mid-century—similar to Britain, Germany, and the United States—where incorporation involved a simple process of registration, which arguably extended the benefits of the corporate form to a broader set of firms. Indeed, establishments that incorporated in Sweden were smaller than their Russian counterparts, and we provide evidence that the low barriers to incorporation enabled marginal firms to incorporate and expand their operations to a scale where adopting steam became feasible.

More broadly, these findings highlight how underlying institutional differences across countries may shape the choice of organizational form and technology use among firms (e.g., Porta et al. 1998; Kuran 2005; Foreman-Peck and Hannah 2015). Our findings indicate that general incorporation laws that had been enacted in Europe and the United States by the mid-nineteenth century may have facilitated industrial growth partly by enabling firms to leverage the corporate form to grow and adopt new technologies.

Data

Our analysis uses data drawn from the Historical Manufacturing Census of Sweden (*Fabriksberättelserna*), which contains information on Swedish manufacturing establishments during the latter half of the nineteenth century.[6] To oversee the industrial development in the country, the Swedish National Board of Trade (*Kommerskollegium*) tasked local authorities in the cities and the countryside with gathering reports on the performance of all manufacturing establishments in their jurisdiction. Each establishment received a questionnaire every year (see Online Appendix Figure A.1), which had to be returned to the local offices. These questionnaires are now digitized, allowing for an in-depth analysis of Sweden's industrialization at the establishment level.

Our data provide detailed annual information on Swedish manufacturing establishments, which are defined as specific units of production in a given place. While there is an important distinction between a firm and an establishment (e.g., multiple establishments can be owned by the same firm), the distinction between firms and establishments is less relevant for our study since multi-establishment firms were relatively uncommon during our period of analysis (see Online Appendix Figure A.2). For each

[6] See Almås et al. (forthcoming) for a general description of the data and the release of the final data set. A replication package is provided in Berger and Ostermeyer (2025).

establishment, we know the name, location, and industry.[7] Each establishment also reported the number of workers and its output, measured as the total sales value each year. We use this information to calculate a measure of labor productivity as the value of output divided by the number of workers.

Crucially for our purposes, each establishment also reported whether it used steam, water, or animal power in a given year. We focus on the extensive margin of adoption of whether an establishment used a given power source, as contemporaries argued that the reported information on horsepower is likely measured with significant error (Key-Åberg 1898, pp. 193–94). To have a consistent measure of steam usage over the whole period, we define a dummy taking the value of one when an establishment reported using at least one steam engine. We define analogous dummies for animal and water power to measure the use of different power technologies.[8]

Industrial establishments are only categorized as being owned by an individual (male/female) or a company in our data, so corporations are not specifically delineated. However, as emphasized by Jörberg (1961, p. 197), one can reliably identify corporations based on the recorded establishment names on the original questionnaires that establishments submitted. To identify corporations, we search the names of establishments for terms such as *Aktiebolag*, *AB*, or *Limited*, which indicate that an establishment is owned by a corporation.[9] We complement this approach by using two registers that record all Swedish incorporations between 1848 and 1881 (van der Hagen and Cederschiöld 1875, 1882). From these registers, we obtain the year of incorporation, which is matched to the establishments reported in our data. Based on this information, we define a dummy equal to one starting in the first year an establishment is incorporated.

[7] Industries in *Fabriksberättelserna* are harmonized with the industrial classification used in the official national statistics. There are about 40 industries, which are in turn assigned to 12 broad industry groups. Because establishments can be active in more than one industry, we assign the modal industry of each establishment in the analysis. This is not possible for about 2 percent of all observations, which are dropped. However, we document that our main results are similar when including these observations. Online Appendix Figure A.3 displays the number of establishments per year and industry group. The original data were collected separately for urban and rural areas, and we follow this definition in delineating urban areas.

[8] In case an establishment does not report using any power source in year t while at the same time reports using this power source in years $t-n$ and $t+m$, we assume that the establishment also uses the given power source in year t. Necessitated by the underlying assumptions, we assume in the event studies that an establishment continues using steam power in all years after the first adoption.

[9] Specifically, we search for the following terms: *A B*, *AB*, *Aktie*, *Akt.*, *Actie*, *Limited*, and *Ltd* after transforming all strings to lowercase. If an establishment is identified as a corporation while also reporting to have an individual owner, we treat it as a corporation.

As the raw data do not contain an identifier to track establishments over time, we use automatic record linkage algorithms in the spirit of, for example, Ruggles (2002) or Abramitzky, Boustan, and Eriksson (2012) to link establishments into a yearly panel. We briefly outline the underlying procedure here, which is further described in Almås et al. (forthcoming). We start in the first year of our panel and compare all establishments in one region with all establishments in the same location in the following year in terms of industry as well as establishment and owner names. To assess whether such names are similar, we use Jaro-Winkler and Levenshtein distances.[10] We link two observations between years if the industry and name(s) of the owner or establishment are *very similar*, which is the case if the scores exceed our cutoff of 0.9.[11] Crucially, we keep only unique links and repeat this process across all years. Finally, we manually check the resulting panel to correct incorrect links and identify additional ones that were not automatically generated. We show later that potential biases in the linking approach are unlikely to affect our results.

We complement our establishment-level dataset with regional information on bank density. Specifically, we calculate the number of active banks per establishment in each of the 24 Swedish counties (*län*), based on data provided by Häggqvist et al. (2019), which state the name of each limited and unlimited liability bank operating in Sweden since 1866, as well as their period of existence.[12] To calculate bank density, we divide the number of active banks by the number of establishments active in these regions over the same period and use the median value as a cut off to identify regions with relatively better access to banking.

Our main sample is an unbalanced panel of approximately 9,000 industrial establishments that we observe for a total of about 66,000 establishment-years between 1864, when virtually all barriers to entry and incorporation had been removed, and 1890, after which electricity became an

[10] Jaro-Winkler and Levenshtein distances measure the similarity of strings on a scale starting at zero, which increases to one as the names become more similar and eventually identical. These scores are calculated in Stata using commands by Barker and Pöge (2012) and Feigenbaum (2014).

[11] The case studies discussed in the Online Appendix B can serve as illustrative examples. For instance, the brewery in Kristianstad changed its name from *Finlands Bryggeri* to *Finlands Ångbryggeri* to indicate that it was now using steam power in its production. We linked the two observations across years, as the two names have a Jaro-Winkler score of 0.94, which is above our threshold. An alternative would have been to (incorrectly) link the observations of *Finlands Bryggeri* with those of *Wendels Bryggeri*, another brewery in Kristianstad. Our algorithm did not create such links since the Jaro-Winkler value is 0.83, which is below the threshold.

[12] We match the headquarters of each bank to one of the 24 Swedish regions to calculate the sum of years banks were active in each region between 1866 and 1890. Among other information, the data state the total lending per bank. If this equals a positive value, we assume a bank is open. As such, if a region had two banks over the period from 1866 to 1890 and both were active for ten years each, the corresponding value would be 20 for this region.

increasingly viable alternative to steam power. The sample is limited to observations where an establishment is not reported as closed and where the number of workers is recorded.[13] Table 1 provides summary statistics for the main sample used in the analysis, which includes 8,924 establishments, out of which 996 (or about 11 percent) were at some point owned by a corporation. About two-thirds of these establishments were organized as corporations upon entry, while about a third were observed as partnerships or sole proprietorships prior to converting into corporate form. On average, corporations were considerably larger, exhibited higher labor productivity, and were more likely to be located in urban areas compared to non-incorporated establishments. Notably, incorporated establishments also used steam to a much greater extent.

CONTEXT AND DESCRIPTIVE EVIDENCE

The Rise of the Corporation

Sweden's industrial takeoff in the late nineteenth century occurred against the backdrop of a range of liberal institutional reforms.[14] Among the most important was the Companies Act of 1848, which codified the limited liability corporation into law. To incorporate, the 1848 law required firms to divide up the firm's capital into shares, register with the local court, and obtain a charter from the state (Broberg 2008). While the state retained the right to decline a charter, incorporation was liberally granted to businesses. By the 1860s, the procedure had evolved into a general incorporation system that involved a simple registration process (Nilsson 1959). Sweden's transition to a *de facto* system of general incorporation coincided with a similar transition in other European countries.[15]

[13] We drop about 9,000 observations due to missing information on workers after the assignment of a modal industry and the exclusion of closed establishments. However, we provide robustness checks showing that our main results are similar when including these observations.

[14] In 1846, the guild system was dismantled, and the Statute on Freedom of Trade in 1864 enabled any person of legal age to start a business. These liberal institutional reforms sharply reduced barriers to entry and are often emphasized as central to the rapid pace of Swedish industrialization (e.g., Schön 2012, pp. 130–31). Similarly, Foreman-Peck and Hannah (2015) underline the role of liberalization of industrial and trade policies in accounting for the high prevalence of corporations in Sweden and other Scandinavian civil law countries.

[15] While U.S. states such as Massachusetts (in 1809) and New York (1811) were the first to introduce general incorporation laws, European countries like Germany (1871), France (1867), and the United Kingdom (1855–56) saw a similar transition around mid-century (Guinnane et al. 2007). Sweden's joint-stock law was modernized in 1895, marking the formal transition to a *de jure* registration system.

TABLE 1
SUMMARY STATISTICS

	All				Incorporated		Non-Incorporated	
	Mean	SD	Min	Max	Mean	SD	Mean	SD
Steam power	0.25	0.44	0.00	1.00	0.66	0.47	0.20	0.40
Water power	0.22	0.41	0.00	1.00	0.32	0.47	0.21	0.40
Animal power	0.11	0.32	0.00	1.00	0.05	0.22	0.12	0.33
Workers	24.63	68.85	1.00	1382.00	102.31	151.14	14.18	37.19
Sales	69.34	258.73	0.00	7527.74	342.55	622.00	32.68	112.52
Sales/worker	2.32	5.69	0.00	376.62	3.88	7.84	2.12	5.30
City	0.45	0.50	0.00	1.00	0.52	0.50	0.44	0.50
Number of observations	66,021				7,830		58,191	
Number of establishments	8,924				996		8,251	

Notes: This table presents summary statistics for the establishments included in our main sample. Sales (also per worker) is reported in 1,000s SEK and is missing for about 3,500 observations. Note that the reported summary statistics include establishments that were active for only one year, which are, by design, excluded in the panel regressions. See the main text for more details about the data and sample restrictions.
Source: *Fabriksberättelserna*.

The corporation became an increasingly dominant organizational form in Swedish industry over the latter half of the nineteenth century. Figure 1 shows that the share of industrial establishments owned by corporations was about 2 percent in the mid-1860s, which rapidly increased starting with the industrial boom of the 1870s. By 1890, the share of establishments owned by corporations had increased to about 20 percent.[16] Although most corporations were newly formed, about a third of all establishments owned by corporations had existed in another organizational form as partnerships or sole proprietorships prior to incorporation (see Figure 1). We use these conversions into corporate form as the basis for our main empirical analysis.

Why do firms choose to incorporate? Two main advantages have been emphasized. First, incorporation grants owners the right to operate under limited liability so that owners are not liable for claims exceeding their original investments. Second, incorporation facilitates access to debt and equity markets, as shares can be used as collateral to obtain long-term financing.

Historians have emphasized that establishing limited liability for owners was a central reason for incorporation (Broberg 2008). Its role can be exemplified in the engineering industry, where many small firms

[16] When considering the fact that establishments owned by corporations were considerably larger, the growing role of corporations becomes even more apparent: corporations accounted for more than half of all workers and industrial output by the late 1880s (Jörberg 1961, p. 200). Moreover, corporate ownership was common throughout Sweden (Online Appendix Figure A.5).

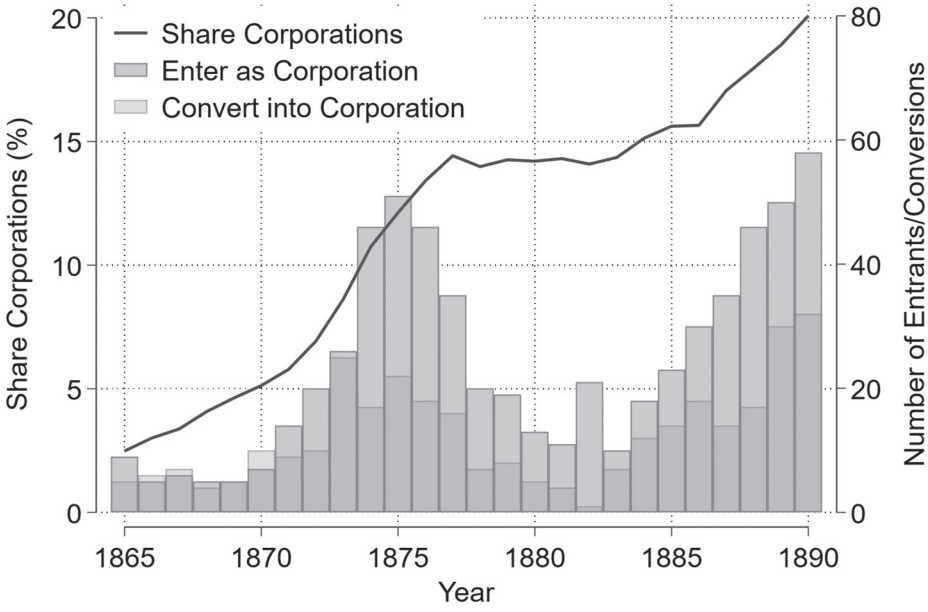

FIGURE 1
THE RISE OF THE CORPORATION

Notes: This figure displays the share of establishments owned by corporations and the yearly number of establishments that enter our data as corporations and convert to the corporate form, respectively. See the main text for more details about the data and sample restrictions.
Source: *Fabriksberättelserna*.

built their businesses on exploiting new products or inventions. Without the status of limited liability, few individuals would have been willing to invest their own capital in these risky ventures (Jörberg 1961, p. 209). Moreover, the role of limited liability is evident from the fact that incorporation often involved no change in the ownership of firms. After incorporation, firms were often closely held, with ownership remaining in the hands of the initial owner or family (Jörberg 1961, p. 198).[17]

However, contemporaries also emphasized that incorporation facilitated access to capital.[18] In particular, incorporation enabled firms to use

[17] Gårdlund (1942, p. 199), for example, emphasizes the fact that the conversion to the corporate form in the iron industry or in mechanical workshops such as Bolinders or Kockums mainly involved a formal change in ownership structure. After incorporation, the firms were controlled by a small number of shareholders, often members of the same family. The fact that such firms converting to the corporate form were often well-established, with little need for additional capital, further underlines the role of limited liability as a central motive behind incorporation (Gårdlund 1947, p. 39).

[18] C. F. Waern, a wholesale merchant in Gothenburg, emphasized this when he, in a letter dated 1876, wrote that: "if it [the firm] may definitely be considered to be able to *become a good one* but with a larger capital than we are able or desire to use on it, then we may incorporate" (Jörberg 1961, p. 199). A similar rationale is evident among the many iron works that were converted into corporate form in the 1870s to raise new investment capital (Broberg 2006, p. 201).

shares as collateral for loans to secure long-term financing for investments.[19] While lending backed by shares was of minor importance in the 1860s, commercial banks quickly expanded share-backed lending as the rate of incorporation increased in the 1870s and late 1880s (Broberg and Ögren 2019). The rise of the corporate form led to increased involvement of banks in industrial development, which had become an increasingly important source of industrial capital by the end of the century (Gårdlund 1947; Broberg 2008; Ögren 2009; Schön 2012).

Corporations and the Diffusion of Steam Power

Steam technology diffused slowly in Sweden during the first half of the nineteenth century, but it gradually grew to become the most common source of power by the end of the century. Figure 2A shows that only about 10 percent of industrial establishments reported using steam in the early 1860s. By 1880, about 27 percent of establishments relied on steam power. While direct comparisons should be made with care, these numbers place Swedish industry slightly ahead of American manufacturing, where 22 percent of establishments used steam in the same year (Atack, Bateman, and Margo 2008). A decade later, about 41 percent of Swedish industrial establishments had installed at least one steam engine.[20]

The adoption of steam required establishments to operate at a relatively large scale and often involved a complete reorganization of the factory.[21] Larger establishments had a cost advantage because they could rely on more cost-efficient and larger engines (Devine 1983). Moreover, the productivity gains after adopting steam were greater in large establishments because they enhanced the division of labor (Atack, Bateman, and Margo 2008; Atack, Margo, and Rhode 2022). On cost grounds, larger establishments thus had clear incentives to prefer steam over water in the latter half of the nineteenth century (Atack 1979).

[19] A common misconception is that the corporate form enabled firms to mobilize capital from a large number of small savers. The nominal value of stocks in industrial firms was typically high enough to restrict the circle of potential investors to commercial banks or exceptionally wealthy individuals (Gårdlund 1942, pp. 197–98).

[20] A similar increase is also evident in terms of aggregate horsepower. While steam engines accounted for about 1 percent of motive power in Swedish industry by the mid-nineteenth century, they grew to account for more than half of aggregate industrial horsepower by the end of the century (Prado 2014).

[21] To introduce steam, the physical layout of establishments often had to be completely reorganized to accommodate the transmission systems with pulleys and belts that delivered power from the engine to machines, which sometimes were required to cover large distances as they needed to connect multiple buildings (Devine 1983). We provide examples of how industrial establishments were often completely restructured to accommodate the adoption of steam in Online Appendix B.

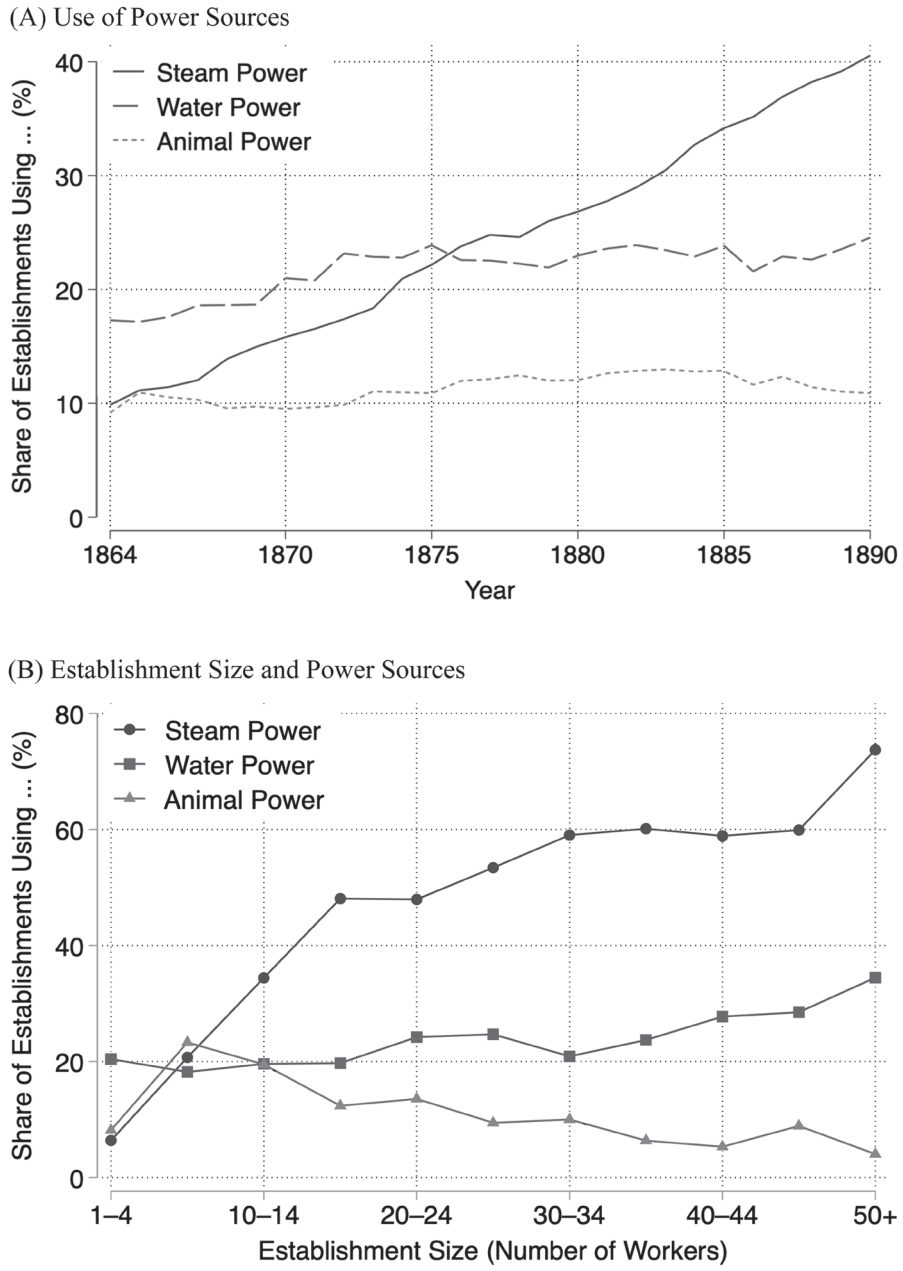

FIGURE 2
THE DIFFUSION OF STEAM POWER

Notes: Panel A: This figure displays the yearly share of establishments using steam, water, and animal power. Note that an establishment can use more than one power source at a time. Other power sources played a negligible role and are thus excluded. Panel B: This figure displays the share of establishments that use steam, water, and animal power across different size classes between 1864 and 1890. See the main text for more details about the data and sample restrictions. *Source*: *Fabriksberättelserna*.

Figure 2B shows that larger establishments, indeed, were substantially more likely to rely on steam, while traditional power sources (animals or water) were less scale-dependent. Steam use was considerably higher among establishments with 15 or more workers, yet the median industrial establishment in our sample employed just five workers.[22] The fact that most industrial establishments were too small to benefit from adoption has sometimes been cited to explain the slow diffusion of steam in Sweden (Prado 2014).[23]

Corporations may have had an advantage in adopting steam given their larger size and the greater scale requirements of steam technology (see Table 1). Indeed, corporations spearheaded the adoption of steam. Industrial establishments owned by corporations were more than three times as likely to rely on steam power compared to establishments owned by partnerships or sole proprietorships (see Table 1).[24] Similarly, the diffusion of the corporate form and steam power was deeply intertwined across industries. Figure 3 displays the share of establishments that were incorporated as well as the share of establishments using steam between 1864 and 1890 across 12 broad industry groups. Industries where the corporate form was more prevalent—such as the food and beverages, metals, or wood industries—also had adopted steam power to a greater extent.[25] However, such differences in steam use could also be attributed to the larger establishment size in these industries or the fact that corporations, for example, were larger and more likely to be located in urban areas (see Table 1). We next provide econometric evidence showing that the link between an establishment's incorporation and adoption of steam likely captures a causal relationship.

EMPIRICAL ANALYSIS AND RESULTS

This section documents that incorporation was a key driver of the adoption of steam power among Swedish manufacturing establishments in the late nineteenth century. We first examine pooled OLS regressions showing that corporations were more likely to use steam power. To identify the

[22] Atack, Bateman, and Margo (2008) find a similar pattern among U.S. manufacturing establishments, showing that steam use is significantly higher among "factories", defined as establishments with 16 or more workers.

[23] Additional arguments for the slow adoption of steam include the fact that Sweden's industrialization, to a large extent, took place in rural areas where access to capital and output markets was more limited (Gårdlund 1942). Indeed, more urban regions—for example, Stockholm, Göteborg and Bohus, and Malmöhus County—stood out with a rapidly growing share of establishments using steam engines (see Online Appendix Figure A.4). Relatedly, the rural location of many establishments meant that they could rely on Sweden's extensive supply of hydropower.

[24] Notably, differences in steam use between corporations and non-corporations remained relatively stable over the period of study (see Online Appendix Figure A.7).

[25] While differences in steam use exist across industries, steam had become the most common source of power in nearly all industries by 1890 (see Online Appendix Figure A.6).

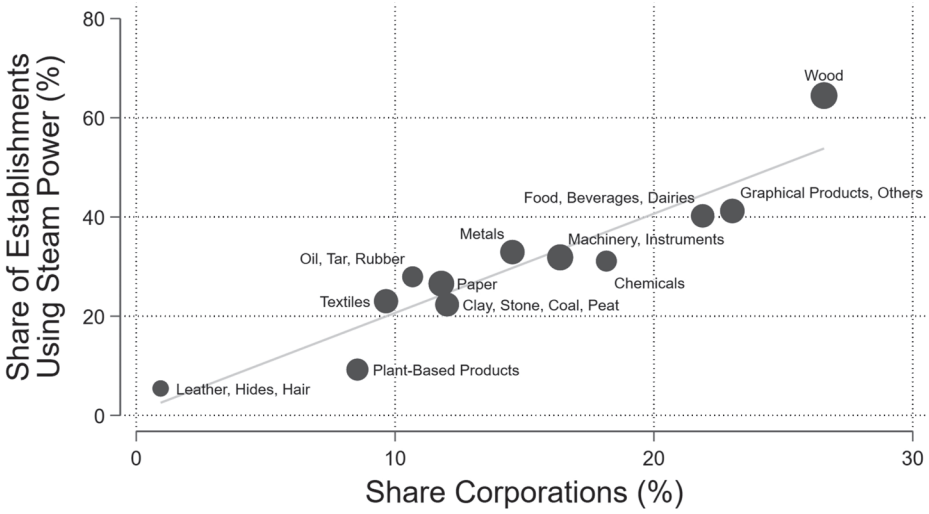

FIGURE 3
INCORPORATION AND STEAM USE ACROSS INDUSTRIES

Notes: This figure displays the share of industrial establishments that report using steam power and that are incorporated across 12 broad industry groups between 1864 and 1890, as well as a best-fit line from a linear regression. The size of the circles corresponds to the mean size of establishments within each industry group, as measured by the log number of workers. See the main text for more details about the data and sample restrictions.
Source: *Fabriksberättelserna*.

impact of incorporation, we then examine establishments that converted to the corporate form in a difference-in-differences and event-study framework, showing that the probability of an establishment adopting steam increases significantly after incorporation. Exploring the heterogeneous impacts of incorporation, we find that it particularly benefited smaller establishments in rural areas characterized by lower bank density. Lastly, we provide evidence that incorporation allowed such marginal establishments to expand to a scale where steam became a feasible technology to use.

Incorporation and the Adoption of Steam Power

OLS ESTIMATES

We begin by estimating simple pooled OLS regressions of the following form:

$$Y_{it} = \phi_t + \beta Corporation_{it} + \mathbf{X}'_{it}\delta + \varepsilon_{it} \quad (1)$$

where Y is a dummy taking the value of one if establishment i used steam power in year t and zero otherwise. *Corporation* is similarly a dummy

TABLE 2
CORPORATIONS AND THE USE OF STEAM POWER: OLS ESTIMATES

	Establishment Uses Steam Power = 1					
	(1)	(2)	(3)	(4)	(5)	(6)
Corporation = 1	0.424***	0.413***	0.142***	0.099***	0.105***	
	(0.019)	(0.019)	(0.020)	(0.019)	(0.019)	
Always incorporated = 1						0.096***
						(0.023)
Incorporating establishment = 1						0.123***
						(0.027)
City = 1		0.128***	0.057***	0.081***	0.068***	0.068***
		(0.011)	(0.010)	(0.011)	(0.012)	(0.012)
6–15 workers = 1			0.176***	0.195***	0.191***	0.191***
			(0.011)	(0.012)	(0.012)	(0.012)
16–50 workers = 1			0.396***	0.442***	0.434***	0.434***
			(0.016)	(0.017)	(0.017)	(0.017)
Above 50 workers = 1			0.566***	0.625***	0.610***	0.609***
			(0.021)	(0.022)	(0.022)	(0.022)
Year FE	Yes	Yes	Yes	No	No	No
Industry-by-year FE	No	No	No	Yes	Yes	Yes
Region-by-year FE	No	No	No	No	Yes	Yes
Number of observations	66,021	66,021	66,021	66,010	66,010	66,010
Number of establishments	8,924	8,924	8,924	8,924	8,924	8,924
Mean dependent variable	0.254	0.254	0.254	0.254	0.254	0.254

Notes: OLS regressions. Standard errors clustered at the establishment level are reported in parentheses. See the main text for more details about the data and sample restrictions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: *Fabriksberättelserna*.

variable taking the value of one starting in the year that an establishment is incorporated. The baseline regressions include a full set of year fixed effects (ϕ_t) that control for the fact that steam use increased over time. In additional specifications, the vector **X** contains a set of controls capturing other factors that may have shaped the use of steam or industry- and region-by-year fixed effects controlling for time-varying shocks across industries and regions. Throughout the analysis, we cluster standard errors at the establishment level.

Table 2 reports OLS estimates of Equation (1). Column (1) shows that establishments owned by corporations were 42 percentage points more likely to use steam power compared to non-incorporated establishments, which is a large difference considering that only about one in four establishments used steam in the sample. However, the bivariate association between incorporation and steam use may reflect the fact that

incorporated establishments, for example, were considerably larger and more likely to be located in urban areas (see Table 1). We next examine the robustness of the link between incorporation and steam use while controlling for such characteristics.

A key virtue of the steam engine was that it reduced the locational constraints imposed by water power, which may have facilitated a clustering of establishments in urban locations (Rosenberg and Trajtenberg 2004; Kim 2005). Column (2) adds a dummy taking the value of one if an establishment is located in an urban area. Establishments in urban areas were about 13 percentage points more likely to use steam. However, controlling for an establishment's geographical location has a marginal impact on the association between incorporation and steam use.

Given that steam power requires establishments to operate at a larger size, the number of workers may be a key predictor of steam use (Atack, Bateman, and Margo 2008). Column (3) adds a set of dummies capturing whether establishments employed 6–15, 16–50, and above 50 workers. The probability of using steam increases with establishment size. For example, an establishment employing more than 50 workers was about 57 percentage points more likely to use steam relative to establishments employing five or fewer workers (the omitted reference category). Notably, controlling for establishment size sharply reduces estimated differences in steam use between incorporated and non-incorporated establishments. Thus, a potential mechanism explaining the higher steam use among corporations is that they operate at a larger size.[26]

A range of omitted variables may still explain the association between corporate status and steam use. For example, steam use differed considerably across industries (see Figure 3). To flexibly control for a variety of such industry factors, we add a full set of industry-by-year fixed effects corresponding to our 12 industry groups in Column (4). While the association between incorporation and steam use is reduced, there remains a large positive and statistically significant association. Similarly, spatial differences in, for example, population, fuel prices, or market access may correlate with both the organizational form of establishments and steam use. Therefore, we add a full set of region-by-year fixed effects for the 24 Swedish counties (*län*) to absorb time-varying regional shocks in Column (5). Notably, the association between incorporation and steam use remains virtually unchanged.

[26] Notably, controlling for size also reduces the estimated association between being located in an urban area and steam use. These results are consistent with Kim (2005), emphasizing that the more extensive use of steam in urban locations in the United States mainly reflects the larger average size of establishments located in cities.

In sum, these results document a statistically and economically significant association between corporate ownership and the use of steam technology. However, interpreting this association as a causal relationship is challenging since it may still reflect a range of unobserved establishment characteristics that we cannot control for. Therefore, we next leverage within-establishment variation in incorporation and steam adoption.

DIFFERENCE-IN-DIFFERENCES ESTIMATES

To identify the impact of incorporation on steam adoption, we use the fact that about a third of all corporations in our sample are observed either as a partnerships or sole proprietorships prior to incorporation. Such conversions provide an opportunity to leverage within-establishment variation in corporate form to isolate the impact on the use of steam technology in a difference-in-differences framework.

Our primary difference-in-differences specification takes the following form:

$$Y_{it} = \gamma_i + \phi_t + \beta Corporation_{it} + \mathbf{X}'_{it}\delta + \varepsilon_{it} \quad (2)$$

where Y is a dummy taking the value of one if establishment i uses steam power in year t. *Corporation* is a dummy taking the value of one starting in the year an establishment incorporates and zero for the years prior. We control for establishment fixed effects (γ_i), capturing time-invariant and establishment-specific factors, meaning that the identifying variation is driven by establishments that we observe both before and after incorporation. We also include a full set of year fixed effects (ϕ_t) that absorb differences in steam use across years. In additional specifications, the vector $\mathbf{X}$ includes other establishment-level controls as well as industry- and region-by-year fixed effects to absorb temporal shocks that are common to all establishments within the same industry or region. Again, standard errors are clustered at the establishment level.

Table 3 presents estimates of Equation (2). Column (1) shows that incorporation significantly raised the probability that an establishment adopted steam by about 7 percentage points, which is roughly a third of the sample mean. In Columns (2) and (3), we include a full set of industry- and region-by-year fixed effects. While the estimated link between incorporation and adoption of steam is slightly reduced, there remains an economically and statistically significant effect. We provide

TABLE 3
INCORPORATION AND THE ADOPTION OF STEAM: DID ESTIMATES

	Establishment Uses Steam Power = 1				
	(1)	(2)	(3)	(4)	(5)
Corporation = 1	0.073***	0.058***	0.055**	0.045**	0.044**
	(0.021)	(0.022)	(0.022)	(0.023)	(0.020)
Establishment EE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	No	No	No
Industry-by-year FE	No	Yes	Yes	Yes	Yes
Region-by-year FE	No	No	Yes	Yes	Yes
Initial size-by-year FE	No	No	No	Yes	Yes
Linear establishment trends	No	No	No	No	Yes
Number of observations	63,892	63,879	63,879	63,879	63,879
Number of establishments	6,795	6,795	6,795	6,795	6,795
Mean dependent variable	0.255	0.255	0.255	0.255	0.255

Notes: OLS regressions. Standard errors clustered at the establishment level are reported in parentheses. Initial establishment size is measured through dummies denoting whether a given establishment employed 1–5, 6–15, 16–50, or 50+ workers in the first year we observe it. See the main text for more details about the data and sample restrictions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: *Fabriksberättelserna*.

additional evidence in the Online Appendix that our baseline results are similar when using alternative samples.[27]

A central empirical concern is that selection into corporate form may drive our results.[28] While the baseline results control for time-invariant establishment-level characteristics that may affect selection, they do not

[27] In particular, we explore the robustness of the results in Online Appendix Table A.1 where we present similar estimates imposing different restrictions on our sample: (*i*) including establishment-years with missing information on the number of workers; (*ii*) including establishments that we cannot assign to a unique industry; (*iii*) only including a balanced panel where we observe each establishment in each year from entry until exit or the end of our study period; and (*iv*) excluding establishments that may incorrectly contain data from other establishments in the area. The estimated impacts of incorporation in these alternative samples are very similar to our baseline estimates reported in Table 3. We also show that the results are similar when dropping potential outliers in terms of establishment size (Online Appendix Table A.2). Notably, the observation that our results do not appreciably change when using balanced or trimmed samples is also an implicit robustness check of our linking approach. Arguably, the balanced sample provides higher-quality links, and the trimmed samples show that even if our linking algorithm, for example, performs better for large establishments, this circumstance does not explain our findings.

[28] A related concern is that establishments that enter as corporations and those that convert into corporate form may differ. However, the last column of Table 2 includes two separate dummies for: (*i*) establishments that were founded as corporations or that incorporated prior to 1864, the beginning of our period of analysis; and (*ii*) establishments that converted into corporate form. Both types of corporations had a similar and higher probability of using steam power compared to non-incorporated establishments, which suggests that establishments that converted into the corporate form may also be informative about the broader population of corporations. We also examine mean differences between both types of corporations in terms of a richer set of establishment-level characteristics, including technology use, size, productivity, and geography in Online Appendix Table A.3. Overall, we find small differences between establishments that switch to become corporations and those that are incorporated in every period we observe them, though the former tend to be slightly less productive and more likely to be located in rural areas.

account for potential selection into incorporation due to time-varying characteristics. A priori, selection into corporate status could be positive or negative. To examine the extent of selection into corporate form, we estimate establishment-level OLS regressions, where we regress employment, output, and labor productivity on a dummy that takes the value of one if an establishment incorporates in the next period (see Online Appendix Table A.4).[29] These results reveal that establishments that incorporated in the next period were slightly larger in terms of employment and output, though there is no evidence that they had higher labor productivity. While the evidence is not conclusive, event-study estimates in Online Appendix Figure A.9 suggest that incorporating establishments did not experience a differential trend in employment, output, or labor productivity prior to incorporation.

To examine whether selection on establishment size may affect our estimates, we first interact initial establishment size before incorporation, as measured by the number of workers, with a full set of year fixed effects in Column (4) of Table 3. While the estimated magnitude declines somewhat, it still suggests that incorporation was associated with about a 5 percentage point increase in the probability of adopting steam. Another way to address potential selection is to allow for differential growth paths. In Column (5), we include a full set of linear establishment trends, which suggests that incorporation led to about a 4 percentage point increase in steam adoption.

Taken together, the fact that establishments selecting into incorporation were slightly larger prior to incorporation does not seem to account for the fact that the adoption of steam increased after incorporation.[30] However, to further reduce concerns of selection into incorporation, we next present event-study estimates that also allow us to rely solely on the timing of incorporation among the subset of establishments that, at some point, incorporated for identification.

EVENT-STUDY ESTIMATES

To estimate our event-study models, we follow Sant'Anna and Zhao (2020) and Callaway and Sant'Anna (2021). Their approach involves estimating multiple difference-in-differences regressions to obtain individual

[29] The sample of establishments is limited here to those that are not incorporated in year t, which means that the estimates capture mean differences in establishment outcomes among those that incorporate in the following year relative to establishments that remain unincorporated.

[30] The fact that we document below that the increase in steam adoption after incorporation is mainly driven by initially smaller establishments further suggests that selection based on size is not driving our main results.

treatment effects for groups of establishments that are treated in a specific year. Crucially, only never-incorporated or not-yet-incorporated establishments are used as comparison groups. In the second step, a weighted average is used to summarize the individual effects into an overall effect, with the weights corresponding to the size of the groups. Alternatively, one can also specify a dynamic version to conduct event studies, where the time since treatment is standardized across groups before the corresponding treatment effects are averaged.[31]

Figure 4 displays event-study estimates and 95 percent confidence intervals. Figure 4A compares steam adoption among establishments that incorporate relative to establishments that never incorporate. Prior to incorporation, there were no significant differences in steam use. After incorporation, however, there was a sizable and statistically significant increase in the probability of adopting steam. The average of the group-time average treatment effects on the treated for the five years after incorporation is about 6 percentage points (*p-value* < 0.01), which is very similar to the difference-in-differences estimates presented in Table 3.

To further reduce concerns that selection drives the results, Figure 4B compares incorporated establishments with those that are *not yet* incorporated (i.e., the sample is restricted to establishments that become corporations at some point). These estimates identify the effect of incorporation solely from the differential timing of incorporation, which further reduces concerns about selection. Figure 4B shows that there were no significant differences in the use of steam engines in the years prior to incorporation. After incorporation, there was an increase in adoption, although these estimates have less precision, presumably due to the lower number of observations. However, the magnitudes are broadly similar to those in Figure 4A with an average across the group-time average treatment effects on the treated for five years after incorporation of about 4 percentage points (*p-value* $= 0.12$).

Taken together, these results show that industrial establishments were not significantly more likely to rely on steam prior to incorporation, though there was a sharp increase in adoption in the years following incorporation. However, these estimates capture the average effects of incorporation and do not clarify the potential heterogeneous impacts of the corporate form.

[31] To mimic the traditional difference-in-differences setup, we here assume that an establishment continues using steam in all years after the first adoption. See, for example, Marcus and Sant'Anna (2021) for a discussion on the assumptions underlying the different approaches in this section.

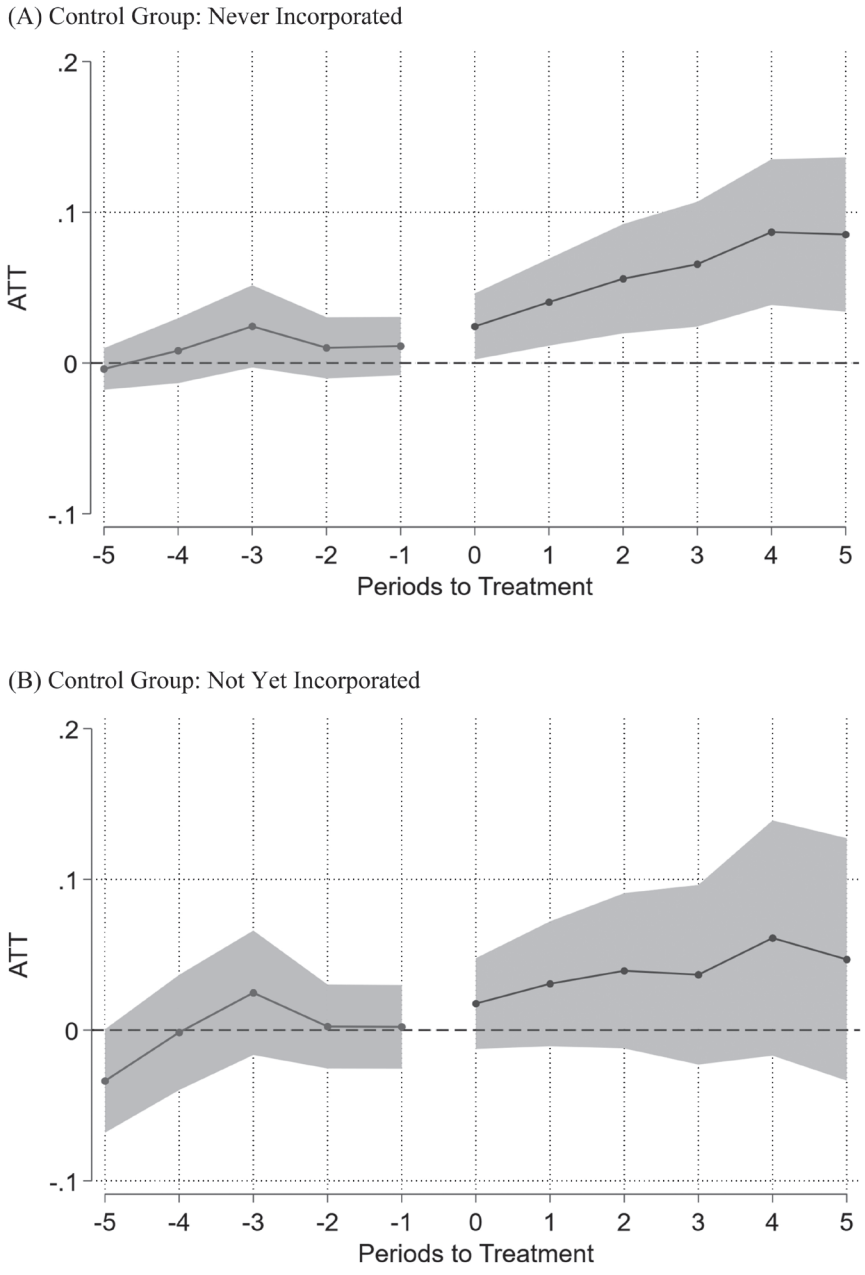

FIGURE 4
INCORPORATION AND THE ADOPTION OF STEAM: EVENT-STUDY ESTIMATES

Notes: This figure presents event-study estimates of the impact of incorporation on the adoption of steam using the approach developed by Sant'Anna and Zhao (2020) and Callaway and Sant'Anna (2021). We report average treatment effects on the treated and 95 percent confidence intervals and use as control group never treated units in Panel A and not yet treated units in Panel B. See the main text for more details about the data and sample restrictions.
Source: *Fabriksberättelserna*.

Incorporation and the Adoption of Steam: The Role of Scale

THE HETEROGENEOUS IMPACTS OF INCORPORATION

Adopting steam involved large capital investments and required many establishments to operate on a greater scale. While incorporating establishments were often large already prior to incorporation, incorporation may have been particularly beneficial for smaller or more credit-constrained establishments if the corporate form facilitated the expansion of an establishment's scale and investment in new technology. To shed light on this question, we examine the heterogeneous impacts of incorporation.

First, we examine whether the impact of incorporation differed among establishments that varied in terms of size prior to incorporation. To do this, we categorize establishments based on the mean number of workers before incorporation.[32] Figure 5 presents estimates from Equation (2) separately for initially small (1–15 workers) and large (16 or more workers) establishments. Notably, a positive and significant effect of incorporation is evident among initially small establishments, while there is no significant increase in steam adoption after incorporation among already large establishments.

Second, Figure 5 compares the impact of incorporation among rural and urban establishments. It may have been more challenging for rural establishments to gain access to long-term financing required to adopt steam, or they may have lacked the technical expertise necessary to install, maintain, and use steam engines. While differences are relatively small, the estimated impact of incorporation was larger among establishments located in rural areas.

Third, we examine whether the adoption of steam differed among establishments with varying access to commercial banks. Figure 5 reports estimates for establishments in regions with above and below median bank density, respectively. A stronger association between incorporation and the adoption of steam in areas with lower bank density suggests that incorporation particularly benefited establishments in areas with less developed local capital markets. Relatedly, Figure 5 shows that the link between incorporation and steam adoption is stronger during the 1860s and 1870s, while it declines in magnitude in the 1880s.[33] A relatively larger effect during early

[32] Online Appendix Figure A.8 displays the number of establishments that converted to corporate form by their size at entry. A large number of initially small establishments converted, which is consistent with our argument that the liberal Swedish incorporation law enabled marginal establishments to incorporate, grow, and eventually adopt steam.

[33] A related question is whether the effects of incorporation varied across the business cycle. As shown in Figure 1, the number of incorporations varies over time, largely reflecting the business cycle. However, Online Appendix Figure A.10 shows that the impact of incorporation gradually declined over time and seemingly does not vary across the business cycle.

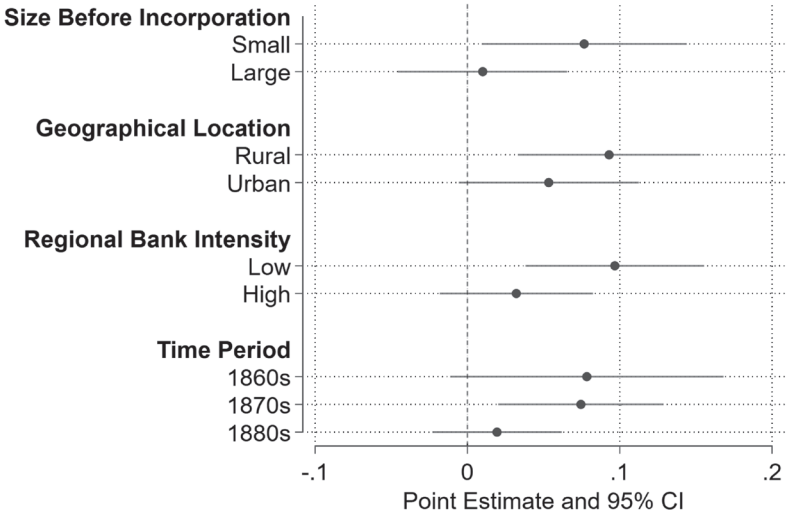

FIGURE 5
HETEROGENEOUS IMPACTS OF INCORPORATION: DID ESTIMATES

Notes: This figure reports OLS estimates and 95 percent confidence intervals from nine individual regressions based on Equation (2). The outcome is a dummy taking the value of one if an establishment uses steam power, which is regressed on a dummy taking the value of one if an establishment is organized as a corporation, controlling for establishment and year fixed effects. In each regression, the sample is respectively restricted to: (*i*) initially small (1–15 workers) and large (16 or more workers) establishments measured as the mean size of establishments in the years before incorporation (note that this corresponds to all years of existence for establishments that never incorporate); (*ii*) whether an establishment is located in a rural or urban area; (*iii*) whether an establishment is located in a region with low/high bank density; and (*iv*) to selected yearly periods (1864–1869, 1870–1879, and 1880–1890). See the main text for more details about the data and sample restrictions.
Source: *Fabriksberättelserna*.

industrialization, when capital markets were less developed, further highlights the potential of the corporate form in overcoming capital constraints.

To bolster the interpretation that incorporation facilitated the adoption of steam among more marginal establishments, we show that incorporation did not lead to the adoption of traditional power sources—animal and water power—that typically did not require firms to operate on a greater scale (Online Appendix Table A.5).[34] Moreover, the finding that

[34] Animal power did not entail any great fixed costs compared to the installation of a steam engine, and the use of water power was: (*i*) restricted by geographical factors; and (*ii*) not scalable, thus not requiring establishments to operate at a larger size (see Figure 2B). We focus here on establishments that convert to corporate form, where the adoption of water power may be limited by an establishment's pre-determined geographical location. If we instead focus on entrants that can choose their geographical location, the corporate form may have also facilitated investments in water power. Online Appendix Table A.6 presents cross-sectional regressions where we restrict the sample to entrants observed in their first year (comparing establishments that entered as corporations with other entrants). Establishments that entered as corporations were larger and more likely to rely on water, and especially steam power, relative to other entrants.

more marginal establishments benefited from incorporation in terms of adopting steam is not evident when examining investments in either animal or water power (see Online Appendix Figure A.11).

Taken together, these findings suggest that incorporation primarily facilitated the adoption of steam technology during early industrialization among initially smaller establishments, often located in rural areas with less developed capital markets. Next, we document that incorporation enabled these small firms to expand to a size where steam became a feasible technology to adopt.

INCORPORATION, ESTABLISHMENT SIZE, AND ADOPTING STEAM

A key barrier to the adoption of steam was that many establishments were required to operate at a larger scale than before. Indeed, the use of steam was considerably more common among establishments that employed 15 or more workers (see Figure 2B). However, the fact that particularly smaller establishments seem to have benefited from incorporation raises the question of whether incorporation enabled these establishments to expand their operations to a scale where it became feasible to adopt steam.

Figure 6 displays the establishment size distribution, before and after incorporation, among establishments that converted into the corporate form. After incorporation, the size distribution shifted to the right for establishments that adopted steam. However, establishments that did not adopt steam after incorporation did not expand, which suggests that the increase in scale and the adoption of steam were closely intertwined.

To more formally evaluate this mechanism, Table 4, Panel A, presents estimates similar to Equation (2) where the outcome is the number of workers in each establishment. Column (1) shows that an establishment after incorporation saw an increase of about 24 additional workers, which implies that an establishment approximately doubled in size considering that the average establishment employed 25 workers.[35] Columns (2) and

[35] We corroborate these results using an event-study approach in Online Appendix Figure A.9, documenting a sustained increase in employment after incorporation. However, one may wonder whether establishments that used steam were simply larger because the new technology allowed for year-round operation (see, e.g., Gregg and Matiashvili 2022). Unfortunately, our data do not contain information on the number of working days per establishment. However, the 1910 edition of *Fabriksberättelserna* reports the total number of working days worked by all workers in a given establishment. We digitized this information for a selected number of regions. Online Appendix Figure A.12 suggests that the number of working days per worker did not appreciably differ between establishments that used steam and those that did not. Moreover, establishments generally reported their average number of employed workers in a given year (Jörberg 1961, pp. 374–75), so establishments can be compared in terms of their size.

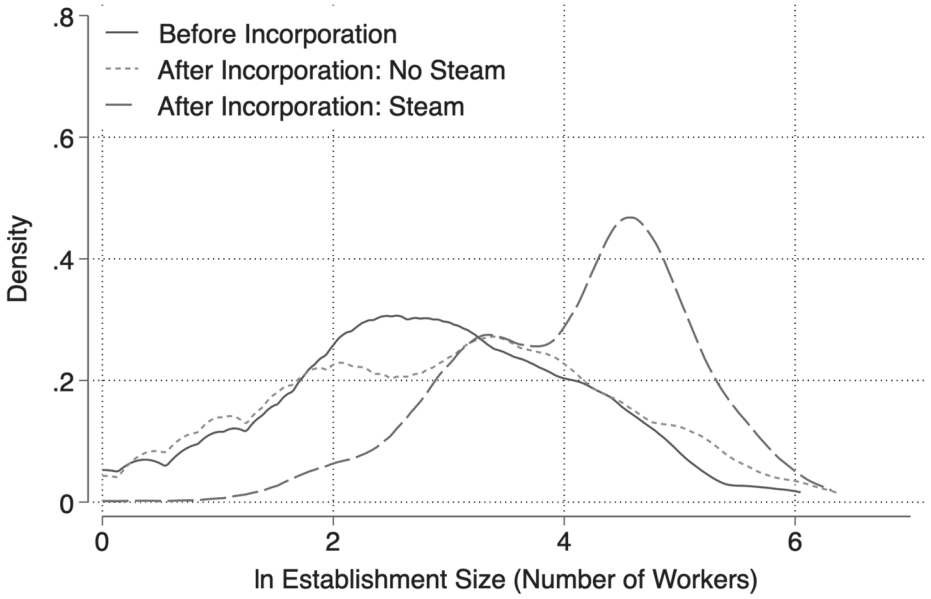

FIGURE 6
ESTABLISHMENT SIZE BEFORE AND AFTER INCORPORATION

Notes: This figure shows Kernel density estimates (using an Epanechnikov kernel with a half-width of 0.25) of establishment size measured as the log number of workers for: (*i*) establishments before incorporation that did not use steam; (*ii*) establishments that after incorporation used steam; and (*iii*) establishments that after incorporation did not use steam. We exclude establishments that used steam in all years and those that never incorporated. See the main text for more details about the data and sample restrictions.
Source: *Fabriksberättelserna*.

(3) present separate regressions for establishments differentiated by their average size before incorporation, again defined as small (1–15 workers) and large (16 or more workers) establishments.[36] While the absolute increase in size after incorporation was higher in initially larger establishments, the relative increase was largest in initially small establishments. More importantly, the average small establishment employed just four workers and was therefore too small to use steam technology. However, after incorporation, such establishments approximately doubled in size, thus approaching the size threshold where steam use was substantially higher (see Figure 2B).

Can increases in size among initially smaller establishments account for the increased use of steam after incorporation? Table 4, Panel B presents estimates of Equation (2), where the outcome is a dummy capturing whether an establishment uses steam. Columns (4) and (6) show that

[36] By construction, establishments that enter as corporations are thus disregarded in the regressions where we separate by size (since we do not observe their size prior to incorporation).

TABLE 4
INCORPORATION, ESTABLISHMENT SIZE, AND STEAM ADOPTION: DID ESTIMATES

Dependent Variable:	Panel A: Number of Workers			Panel B: Steam Power = 1			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Size before Incorporation:	All	Small	Large	Small	Small	Large	Large
Corporation = 1	24.451***	4.995***	22.312***	0.077**	0.033	0.010	0.004
	(3.702)	(1.099)	(4.592)	(0.034)	(0.032)	(0.028)	(0.028)
Workers					0.869***		0.028*
					(0.122)		(0.015)
Establishment FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	63,892	45,739	13,211	45,739	45,739	13,211	13,211
Number of establishments	6,795	5,106	1,169	5,106	5,106	1,169	1,169
Mean dependent variable	25.009	4.336	67.210	0.118	0.118	0.581	0.581

Notes: OLS regressions. The independent variable Workers measures the sum of workers employed at the establishment in 100s. Standard errors clustered at the establishment level are reported in parentheses. See the main text for more details about the data and sample restrictions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: *Fabriksberättelserna*.

incorporation is only associated with an increased probability of steam adoption among initially small establishments. In Columns (5) and (7), we include a time-varying control for the number of workers employed. Controlling for size reduces the association between incorporation and steam adoption, both in magnitude and statistical significance among initially small establishments, suggesting that increases in size partly account for the higher probability of adopting steam.

Together, these findings suggest that Sweden's liberal incorporation system initially benefited smaller establishments by enabling them to expand to a size where adopting steam became feasible. To support this interpretation, we provide case study evidence in Online Appendix B showing that many small firms actively used incorporation to grow and adopt steam power.[37] We further corroborate this argument by comparing Swedish corporations with the only country for which similar data is available: Imperial Russia (Gregg 2020). Russia lacked a general incorporation law, and firms were required to undergo a costly process to incorporate. Consistent with the lower barriers to incorporation in Sweden, Swedish establishments that incorporated during our period were much smaller

[37] An informative example is the small traditional brewery *Finlands Bryggeri* in the city of Kristianstad, founded as a company in 1869. To expand and start production of Bavarian beer, the firm incorporated in 1883. In the following year, the transition to steam technology began, requiring a complete reorganization of the establishment. To accommodate the shift to steam technology, new multi-story brick buildings and an adjacent building for the steam boiler and chimney were constructed (Wikipedia 2023). In the year of incorporation, the establishment reported a total of 11 workers, which increased to 18 workers when steam had been adopted (see Online Appendix Figure B.1). We provide additional examples in Online Appendix B.

compared to Russian establishments that incorporated in the 1890s (Online Appendix Figure A.13).[38] While suggestive, these size differences further underline the fact that Sweden's liberal system of incorporation seemingly enabled marginal firms to access the benefits of the corporate form.

CONCLUSIONS

A puzzling fact is that technologies that can substantially increase firm productivity often diffuse at a slow pace. We examine the adoption of steam technology among manufacturing establishments in Sweden during its industrial breakthrough. While few manufacturing establishments used steam around the mid-nineteenth century, it had become the most common source of power by the end of the century. We show that the transition to steam was spearheaded by corporations. By leveraging the fact that hundreds of establishments converted to the corporate form, we document a plausibly causal link between incorporation and the adoption of steam. A key barrier to the diffusion of steam was that most establishments were too small to adopt steam technology. Yet we find that Sweden's liberal system of incorporation enabled many smaller establishments to leverage the benefits of the corporate form to expand to a greater scale where steam became a feasible technology to adopt. The institutional changes embodied in Sweden's system of incorporation thus contributed to technological diffusion and ultimately to its catch-up with the leading industrial nations.

REFERENCES

Abramitzky, Ran, Leah Platt Boustan, and Katherine Eriksson. "Europe's Tired, Poor, Huddled Masses: Self-Selection and Economic Outcomes in the Age of Mass Migration." *American Economic Review* 102, no. 5 (2012): 1832–56.

Almås, Ingvild, Thor Berger, Timo Boppart, Konrad Burchardi, Olof Ejermo, Björn Eriksson, Anders Larsson, Hannes Malmberg, Stefan Maukner, Mats Olsson, and Vinzent Ostermeyer. "Historical Manufacturing Census of Sweden: Data Description and Quality Assessment." *Historical Methods: A Journal of Quantitative and Interdisciplinary History*, forthcoming.

Atack, Jeremy. "Fact in Fiction? The Relative Costs of Steam and Water Power: A Simulation Approach." *Explorations in Economic History* 16, no. 4 (1979): 409–37.

[38] Comparisons should be made with care given that the Russian census aimed to exclude smaller workshops, while the Swedish industrial census, in contrast, included a large number of small establishments. However, such concerns are largely reduced by the fact that we only compare establishments that selected into incorporation. Indeed, as noted by Gregg (2020), the exclusion of small establishments in the Russian census is relatively unimportant in such a comparison, given that very few small firms incorporated.

Atack, Jeremy, Fred Bateman, and Robert A. Margo. "Steam Power, Establishment Size, and Labor Productivity Growth in Nineteenth Century American Manufacturing." *Explorations in Economic History* 45, no. 2 (2008): 185–98.

Atack, Jeremy, Fred Bateman, and Thomas Weiss. "The Regional Diffusion and Adoption of the Steam Engine in American Manufacturing." *Journal of Economic History* 40, no. 2 (1980): 281–308.

Atack, Jeremy, Robert A. Margo, and Paul W. Rhode. "'Automation' of Manufacturing in the Late Nineteenth Century: The Hand and Machine Labor Study." *Journal of Economic Perspectives* 33, no. 2 (2019): 51–70.

———. "'Mechanization Takes Command'?: Powered Machinery and Production Times in Late Nineteenth-Century American Manufacturing." *Journal of Economic History* 82, no. 3 (2022): 663–89.

Barker, Michael, and Felix Pöge. "STRDIST: Stata Module to Calculate the Levenshtein Distance, or Edit Distance, between Strings, Statistical Software Components." Boston College Department of Economics, Boston, MA, 2012. Available at https://ideas.repec.org/c/boc/bocode/s457547.html.

Berger, Thor, and Vinzent Ostermeyer. "Replication for Institutional Innovation and the Adoption of New Technologies: The Case of Steam." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2025-07-02. https://doi.org/10.3886/E227961V2

Bogart, Dan, Sean Bottomley, Max Satchell, and Leigh Shaw Taylor. "Transport Networks and the Adoption of Steam Engines in England and Wales, 1761–1800." Mimeo, 2017.

Broberg, Oskar. *Konsten att skapa pengar. Aktiebolagens genombrott och finansiell modernisering kring sekelskiftet 1900*. Ekonomisk-historiska institutionen vid Göteborgs Universitet, 2006.

———. "The Emergence of Joint-Stock Companies during the Industrial Breakthrough in Sweden." In *Finance and Modernization: A Transnational and Transcontinental Perspective for the Nineteenth and Twentieth Centuries*, edited by Gerald D. Feldman and Peter Hertner, 165–85. Farnham: Ashgate, 2008.

Broberg, Oskar, and Anders Ögren. "Names, Shares and Mortgages: The Formalisation of Swedish Commercial Bank Lending, 1870–1938." *Financial History Review* 26, no. 1 (2019): 81–108.

Callaway, Brantly, and Pedro H. C. Sant'Anna. "Difference-in-Differences with Multiple Time Periods." *Journal of Econometrics* 225, no. 2 (2021): 200–30.

Chandler, Alfred D. *The Visible Hand*. Cambridge, MA: Harvard University Press, 1977.

Clark, Gregory, and David Jacks. "Coal and the Industrial Revolution, 1700–1869." *European Review of Economic History* 11, no. 1 (2007): 39–72.

Comin, Diego, and Bart Hobijn. "An Exploration of Technology Diffusion." *American Economic Review* 100, no. 5 (2010): 2031–59.

Crafts, Nicholas. "Steam as a General Purpose Technology: A Growth Accounting Perspective." *Economic Journal* 114, no. 495 (2004): 338–51.

Crafts, Nicholas, and Abay Mulatu. "How Did the Location of Industry Respond to Falling Transport Costs in Britain Before World War I?" *Journal of Economic History* 66, no. 3 (2006): 575–607.

David, Paul A. "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox." *American Economic Review* 80, no. 2 (1990): 355–61.

de Pleijt, Alexandra, Alessandro Nuvolari, and Jacob Weisdorf. "Human Capital Formation During the First Industrial Revolution: Evidence from the Use of Steam Engines." *Journal of the European Economic Association* 18, no. 2 (2020): 829–89.

Devine, Warren D. "From Shafts to Wires: Historical Perspective on Electrification." *Journal of Economic History* 43, no. 2 (1983): 347–72.

Feigenbaum, James. "JAROWINKLER: Stata Module to Calculate the Jaro-Winkler Distance between Strings, Statistical Software Components." Boston College Department of Economics, Boston, MA, 2014. Available at https://ideas.repec.org/c/boc/bocode/s457850a.html.

Fernihough, Alan, and Kevin H. O'Rourke. "Coal and the European Industrial Revolution." *Economic Journal* 131, no. 635 (2021): 1135–49.

Foreman-Peck, James, and Leslie Hannah. "The Diffusion and Impact of the Corporation in 1910." *Economic History Review* 68, no. 3 (2015): 962–84.

Franck, Raphaël, and Oded Galor. "Technology-Skill Complementarity in Early Phases of Industrialisation." *Economic Journal* 132, no. 642 (2022): 618–43.

Gårdlund, Torsten. *Industrialismens samhälle*. Stockholm, Sweden: Tidens Förlag, 1942.

———. *Svensk industrifinansiering under genombrottsskedet 1830–1913*. Stockholm, Sweden: Svenska Bankföreningen, 1947.

Gregg, Amanda G. "Factory Productivity and the Concession System of Incorporation in Late Imperial Russia, 1894–1908." *American Economic Review* 110, no. 2 (2020): 401–27.

Gregg, Amanda, and Tamar Matiashvili. "Modernization in Progress: Part-Year Operation, Mechanization, and Labor Force Composition in Late Imperial Russia." *Journal of Economic History* 82, no. 4 (2022): 1143–82.

Gregg, Amanda, and Steven Nafziger. "Capital Structure and Corporate Performance in Late Imperial Russia." *European Review of Economic History* 23, no. 4 (2019): 446–81.

Guinnane, Timothy, Ron Harris, Naomi R. Lamoreaux, and Jean-Laurent Rosenthal. "Putting the Corporation in Its Place." *Enterprise & Society* 8, no. 3 (2007): 687–729.

Gutberlet, Theresa. "Mechanization and the Spatial Distribution of Industries in the German Empire, 1875 to 1907." *Economic History Review* 67, no. 2 (2014): 463–91.

Häggqvist, Henric, Peter Hedberg, Lars Karlsson, and Mats Larsson. "The Development of Swedish Commercial Banking, from Establishment to Consolidation: A Presentation of a New Database, 1866–1938." Uppsala Papers in Financial and Business History, Uppsala, Sweden, 2019.

Hall, Bronwyn H. "Innovation and Diffusion." NBER Working Paper No. 10212, Cambridge, MA, January, 2004.

Hall, Bronwyn H., and Beethika Khan. "Adoption of New Technology." NBER Working Paper No. 9730, Cambridge, MA, May, 2003.

Hilt, Eric. "Incentives in Corporations: Evidence from the American Whaling Industry." *Journal of Law and Economics* 49, no. 1 (2006): 197–227.

———. "Corporate Governance and the Development of Manufacturing Enterprises in Nineteenth-Century Massachusetts." In *Enterprising America: Businesses, Banks, and Credit Markets in Historical Perspective*, edited by William J. Collins and Robert A. Margo, 73–102. Chicago, IL: University of Chicago Press, 2015.

Jörberg, Lennart. *Growth and Fluctuations of Swedish Industry 1869–1912: Studies in the Process of Industrialisation*. Stockholm, Sweden: Almqvist & Wiksell, 1961.

Key-Åberg, Karl. "Sveriges industristatistik." In *Statsvetenskaplig Tidskrift*, edited by C. A. Reuterskiöld, Oscar Alin, Hugo Blomberg, and Pontus E. Fahlbeck. Stockholm, Sweden: Almqvist & Wiksell Boktryckeri-Aktiebolag, 1898.

Kim, Sukkoo. "Industrialization and Urbanization: Did the Steam Engine Contribute to the Growth of Cities in the United States?" *Explorations in Economic History* 42, no. 4 (2005): 586–98.

Kuran, Timur. "The Absence of the Corporation in Islamic Law: Origins and Persistence." *American Journal of Comparative Law* 53, no. 4 (2005): 785–834.

Landes, David S. *The Rise of Capitalism*. London, UK: Macmillan, 1966.

Mansfield, Edwin. "Technical Change and the Rate of Imitation." *Econometrica* 29, no. 4 (1961): 741–66.

Marcus, Michelle, and Pedro H. C. Sant'Anna. "The Role of Parallel Trends in Event Study Settings: An Application to Environmental Economics." *Journal of the Association of Environmental and Resource Economists* 8, no. 2 (2021): 235–75.

Nilsson, Carl-Axel. "Business Incorporations in Sweden a Study of Enterprise 1849–1896." *Economy and History* 2, no. 1 (1959): 38–96.

Nuvolari, Alessandro, Bart Verspagen, and Nick von Tunzelmann. "The Early Diffusion of the Steam Engine in Britain, 1700–1800: A Reappraisal." *Cliometrica* 5, no. 3 (2011): 291–321.

Ögren, Anders. "Financial Revolution and Economic Modernisation in Sweden." *Financial History Review* 16, no. 1 (2009): 47–71.

Porta, Rafael La, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert W. Vishny. "Law and Finance." *Journal of Political Economy* 106, no. 6 (1998): 1113–55.

Prado, Svante. "Yeast or Mushrooms? Productivity Patterns across Swedish Manufacturing Industries, 1869–1912." *Economic History Review* 67, no. 2 (2014): 382–408.

Ridolfi, Leonardo, Carla Salvo, and Jacob Weisdorf. "The Impact of Mechanisation on Wages and Employment: Evidence from the Diffusion of Steam Power." CEPR Discussion Paper No. DP17389. London, UK, June 2022.

Rosenberg, Nathan. "Factors Affecting the Diffusion of Technology." *Explorations in Economic History* 10, no. 1 (1972): 3–33.

Rosenberg, Nathan, and L. E. Birdzell, Jr. *How the West Grew Rich: The Economic Transformation of the Industrial World*. New York: Basic Books, 1986.

Rosenberg, Nathan, and Manuel Trajtenberg. "A General-Purpose Technology at Work: The Corliss Steam Engine in the Late-Nineteenth-Century United States." *Journal of Economic History* 64, no. 1 (2004): 61–99.

Ruggles, Steven. "Linking Historical Censuses: A New Approach." *History and Computing* 14, nos. 1–2 (2002): 213–24.

Sant'Anna, Pedro H. C., and Jun Zhao. "Doubly Robust Difference-in-Differences Estimators." *Journal of Econometrics* 219, no. 1 (2020): 101–22.

Schön, Lennart. *An Economic History of Modern Sweden*. Abingdon and New York: Routledge, 2012.

van der Hagen, August L., and Staffan Cederschiöld. Svenska aktiebolag med begränsad ansvarighet, 1848–1874, 1875.

———. Svenska aktiebolag med begränsad ansvarighet, 1848–1882, 1882.

Wikipedia. Finlands bryggeri — Wikipedia, 2023. [Online; accessed 25-January-2024]. Available at https://sv.wikipedia.org/wiki/Finlands_Bryggeri.