Institutional Change and the (Slow) Adoption of New Technologies: The Case of Steam*

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Abstract

This paper analyzes the adoption and impact of steam technology on firm-level outcomes. We leverage novel yearly establishment-level data covering the entire Swedish manufacturing industry in the latter half of the 19$^{\text{th}}$-century. We provide three key results. First, we document descriptively the diffusion of steam power across firms and discuss the relative importance of various underlying drivers including incorporation, social learning, urbanization, and firm size. Second, difference in differences and event study estimates show that the adoption of steam engines raised firm size, output, and labor productivity significantly. For example, adopting a steam engine increased the number of workers at a firm by 37 percent. While both male and female employment expanded, we observe a significant increase in the share of women in the workforce. The share of children in the workforce was unaffected however. Third, we provide evidence of a key complementarity between institutional and technological change: Incorporation raised the probability of adopting steam and incorporated plants grew significantly larger after adoption. We argue that incorporation lowered the risk for firms to install steam engines and improved their access to capital because they operated now under limited liability. More broadly, these results shed light on the complementarities between institutional and technological change: Organizational innovation were required to reap the full benefits of the new technology of steam engines.

JEL Codes: O3, D2, N63

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1 Introduction

A large literature documents a slow rate of adoption of technologies that could seemingly raise firm productivity significantly (Rosenberg, 1972; Hall & Khan, 2003; Hall, 2004). The paradigmatic technology of the Industrial Revolution - steam power - provides a telling example. While contemporary observers ascribed it a central role as an engine behind the emergence of the factory and the accelerated pace of productivity growth, cliometric analysis of the first *General Purpose Technology* paints a less revolutionary picture: Steam power diffused slowly and its growth impacts took a long time to materialize (Crafts, 2004).[1]

A potential barrier to the diffusion of steam was that the new technology required firms to operate their establishments at a larger size than before (Atack et al., 2008). First, steam and the attendant mechanization required a large size to enable a more elaborate division of labor. The adoption of steam often entailed a significant restructuring of production as factories had to be redesigned to accomodate the shafts, belts, and pulleys required to transmit power from the engine to machinery. Second, steam engines were scalable and the engine itself was characterized by increasing returns.

Across most European countries, the majority of 19th-century industrial enterprises were small sole proprietorships. An influential literature underlines the role of the corporate form in accounting for late-19th century growth (Chandler, 1977, 1994; Landes, 1967; Rosenberg and Birdzell, 1986). Modern incorporated firms provided central advantages including access to capital, economies of scale, and managerial inputs. In particular, the rise of the limited liability corporation may have facilitated access to credit, enabled firms to operate at a larger size, partly by lowering risk involved in making significant capital investments.

In this paper, we study the adoption and impact of steam providing evidence of a key complementarity between institutional innovation - the corporation - and technological change. We document that incorporation significantly raised the probability that a firm adopted steam and additional evidence reveal a positive interaction effect on firm size, though not necessarily on labor productivity. The empirical analysis leverage newly digitized annual data on the universe of manufacturing establishments during Sweden's industrialization in the latter half of the 19th-century. The data enables us to follow each individual plant from its inception until its (eventual) demise and observe its adoption of steam. We focus on the period from 1863, when virtually all barriers to entry were removed, to 1895, after which electricity became an increasingly viable alternative to steam power.

Our analysis proceeds in three steps. First, we study the diffusion of steam power. In 1864, when entry barriers were essentially removed, less than 10 percent of plants had installed steam engines, which had increased to almost 40 percent by the early 20th century. We show

[1] Economic historians document that the slow adoption and impact of steam can be extended to other general purpose technologies such as electricity and the personal computer (David, 1990). More broadly, Comin & Hobijn (2010) use data from the past two centuries on the diffusion of 15 major technologies - electricity, steamships, railways, IT, etc. - across 166 countries to document an average adoption lag of 45 years.

that the probability that a firm adopts steam increases discontinuously around the time that it incorporates, which is suggestive of a complementarity between choice of organizational form and technology adoption. We further explore the role of complementary mechanisms showing that adoption increased with firm age consistent with models of learning (XXX), the size of the firm, and being located in an urban area.

Second, we leverage our data to estimate the impact of steam adoption of plant-level outcomes including employment, output, and labor productivity. A central empirical challenge in identifying the impact of steam power is that adoption is likely endogenous: The fact that factories using steam power, for example, were larger and more productive than those that did not may simply reflect the fact that larger and more productive firms were more likely to install and rely on steam power in the first place.[2]

To identify the impact of steam, we use an event study and difference in differences strategy comparing relative changes in outcomes among adopting plants after accounting for unobserved fixed establishment characteristics. Our estimates that leverage within-plant variation reveal large impacts of the adoption of steam on the size of plants measured either in terms of employment or output. After an establishment adopted a steam engine, employment increased by about 37 percent relative to other plants that lacked a central power source, or relied on animal or water power. In that sense, the estimates thus suggest a causal role of steam in accounting for the rise of the factory: plants that adopted steam were significantly more likely to become a factory.[3] A related debate concerns how the coming of steam technology and the rise of large-scale establishments may have been responsible for rising employment of children and women employed in manufacturing (Goldin & Sokoloff, 1981). We show that the adoption of steam led to an increase in employment of both children and women, though only the latter increased in relative terms.

Third, we examine the role of organizational form in shaping impact of steam. Difference in differences estimates show that the impacts of steam on employment and output is significantly larger among incorporated plants. Incorporation thus likely helped firms to exploit the full advantages of steam, presumably choosing to incorporate to gain access to capital markets and reducing risk involved in making significant capital investments. More broadly, these results shed light on the complementarities between institutional and technological change. In other words, organizational innovation were required to reap the full benefits of the new technology.

[2] Atack et al. (2008) use data from the US censuses of manufacturing to document that the likelihood of adopting steam was increasing in plant size. As we discuss in more detail below, the cross-sectional nature of the US census data makes it challenging to disentangle the role of selection and the causal contribution of steam to plant size. A recent contribution by Atack et al. (2019) use data from the US Department of Labor's Hand and Machine Labor study, carried out in the 1890s, to show that the adoption of steam can account for a large fraction of the increased productivity at the level of individual production tasks during the transition to machine labor.

[3] Here we define a factory as a plant employing more than 16 workers...

2 Historical background and Hypotheses

2.1 The adoption of steam engines

The steam engine was the central technology underlying the Industrial Revolution (Rosenberg & Trajtenberg, 2001). It featured major advantages over the traditionally used power sources: Animals, humans, and water. While water power was superior to inanimate sources, it had a crucial set of disadvantages in comparison to steam: Firms using water power could only locate near waterfalls and the supply of power depended on the flow of water. Given the irregular flow of streams across seasons, firms could thus not rely on water power for continuous operations. Water power potentially also hindered future expansion of firms since it was not easily scalable (Atack et al., 2008).

In contrast, steam engines provided many advantages. First, they were more reliable as they provided continuous power. They also eased locational constraints as they enabled firms to move to more suitable places for production. For example, Swedish sawmills adopted steam engines to relocate from waterfalls in the forests to the coasts, which eased production and exports (Schön, 2012).

Second, steam engines were a general purpose technology as they were suitable to mechanize many different steps of production. This had important ramifications for firm-level output and productivity. Since the adoption of a steam engine increased the available capital per worker, labor productivity should increase. Moreover, the steam engine increased specialization and the division of labor within firms. This can be seen by example when comparing steam powered firms to artisanal shops, the more traditional places of industrial production. Whereas one artisan produced a good from start to finish, steam engines allowed workers to specialize in different steps of the production. If mechanization increased the output of one step in the production, firms likely increased employment in the other steps as well so that overall firm-level output rose. The increase in capital per worker and the internal specialization led thus not only to productivity improvements but increased firm-level output and size as well (Atack et al., 2008).

Third, steam engines were also more scalable technology than water power and operated at increasing returns, i.e. larger steam engines provided more power compared to smaller ones for a given unit of inputs. This made steam engines a suitable power source especially for firms with larger output as especially they could reap the benefits of the new technology. Indeed, larger plants were more likely to use steam end noticed larger increases in productivity due to the new technology in the USA (Atack et al., 2008).

For Sweden, the steam engine was an imported technology. The first steam engines were installed in Sweden around 1800 by Samuel Owen, an immigrant from Britain. He had previously worked at the manufacturing firm of James Watt, one of the leading developers of the new technology, and was now tasked with installing steam engines in Sweden. Eventually he stayed and founded his own engine manufacturing firm in Stockholm, which laid the foundation for the long-term development of Swedish steam engines. Many workers trained at his firm and eventually founded their own mechanical workshops (Schön, 2012).

After the 1870s were steam engines well developed and provided enough power to noticeably mechanize production. Consequentially, they became widespread (Magnusson, 2000). A key application of steam engines in Sweden was in the sawmill industry, one of Sweden's leading export sectors of that time. Traditionally, coal was used as a fuel for steam engines but Sweden lacked this natural resource. Sawmills were in a fortunate position as they could use waste wood from the production as an appropriate supplement (Schön, 2012). The steam engine was also quickly adopted in other industries. Appendix A.1 shows that steam engines quickly became the dominant source of power in nearly all manufacturing industries including spinning, machinery, food, chemicals as well as pulp and paper after 1870. This includes thus the leading industries of Sweden's industrialization process, which largely occurred in the second half of the 19$^{\text{th}}$-century (Schön, 2012).

2.2 The rise of the corporation

This breakthrough of the Swedish economy went in hand with substantial institutional reforms. A key aspect was the passing of a law in 1848 removing barriers to incorporation. Traditionally, incorporation was restricted and grated only to selected firms chartered by the state.[4] However, the new law and an extension to it in 1864 removed these barriers to incorporation. Now, incorporation was essentially free: The state granted all firms the corporate status automatically if they met a set of prerequisites (Nilsson, 1959; Schön, 2012).

Incorporation gave firms a set of advantages. Traditionally, firms operated as sole proprietorships or partnerships in which the owners of a firm were directly liable for their business. In contrast, a key advantage of corporations was their status of limited liability. Under limited liability, the owners of a corporation were not liable for claims exceeding their original investments. Additionally, corporations could act as legal entities, which should have facilitated interactions with business partners and ensured that firms did not terminate operations after the death of an owner (Gregg, 2020; Schön, 2012).

Together, these advantages should have made it easier as well as more attractive for corporations to install new machinery such as steam engines. The introduction of limited liability solved a coordination problem by reducing the risks associated with large investments such as installing a steam engine for individual investors. While all investors would profit from the eventually successful deployment of a steam engine, few investors would and could install steam engines alone. The corporate status of firms also facilitated the access to capital either through credits from banks or by issuing stock (Gregg, 2020). And as the advantages of us-

[4] In fact, the probably oldest corporation in the world was Swedish. The Stora Kopparberg Mining Company in Falun was chartered by the state in 1347 (Britannica, 2009).

ing steam power were larger for firms with a sufficient level of output (Atack et al., 2008), especially corporations should have had incentives to install steam engines.

Nilsson (1959) describes three key developments underlying the processes of incorporation in Sweden. First, the right to incorporate was granted fairly liberally to firms. As long as firms fulfilled a set of requirements, a governmental agency automatically granted them corporate status. This automatic procedure was improved over time. Especially after 1860 was incorporation free. This facilitates our analysis since we begin in 1863. There were some restrictions to incorporation around 1890 when many applications were rejected. However, these rejections targeted mainly non-business corporations. These *ekonomiska föreningar* can be regarded as co-operative societies, which were not geared towards generating profits. As we are mainly interested in analyzing the industrial developments, we thus exclude these societies.[5]

Second, the pace with which Swedish firms incorporated varied throughout the 19th-century. It remained quite low until 1865, after which it noticeably increased until 1874. A following contraction was counterbalanced by an increase in incorporations after 1880, so that the total number of incorporated firms largely stagnated until 1895. Most incorporations occurred in the mining and manufacturing industries and to a sizable extent also in the food, leather, chemicals, and raw materials industries.

Third, corporations can either be founded as new enterprises or as conversions from existing enterprises into the corporate form. Nilsson (1959) shows that overall corporations were newly founded enterprises in Sweden and especially so after 1870. New incorporations were roughly double the number of conversions into the incorporated form. However, these relationships varied across industries. Conversions were more common in the metal, mining, iron, lumber, and steel industries. Newly incorporated firms were especially common in textiles as well as the machinery industries. In other industries there is no clear trend. Bankruptcy following incorporation was more common among newly founded corporations as firms that converted into incoporated ownership had allegedly more established business operations. Additionally, mergers between two firms into becoming one corporation were very uncommon.

3 Data

3.1 The Swedish Factory Censuses

We use the Swedish factory censuses to study the diffusion and firm-level impact of steam engines. These factory censuses are a novel dataset yielding detailed insights into the firm-level performance of Swedish manufacturing firms during the late 19th-century.[6] To oversee

[5] Specifically, we exclude them when using the definitions 1, 2 or 4 as defined in Section 3.

[6] For roughly six percent of the observations, we even have information on individual departments within firms. To facilitate the analysis, we collapse these values to firm-level totals and assign the mode of their respective industries to the firm as a whole. Only in about four percent of the subset of firms with multiple departments is this not possible. These observations are dropped from the analysis. We also drop closed firms.

the industrial development in the country, the Swedish National Board of Trade assigned local authorities in cities and the countryside to gather reports on the performance of all firms in their jurisdiction. This was done through questionnaires, which every firm received and had to return to the local offices.[7] While a national summary was then published in the series BiSOS D (SCB, 1910), are the underlying raw data only now digitized for the years 1863 to 1895. These years correspond to our period of analysis.

The data provide us with detailed insights on the population of Swedish manufacturing firms. Among other information, they state the name, location, and industry[8] of the firm as well as the names, gender, and titles of their owner(s) or manager(s).

The data also include information on the performance of the firms such as the value of sales[9] and profits[10] the number of its employees by gender. We use this information to calculate firm-level productivity as $ln(Sales/Workers)$. Total factor productivity (TFP) is calculated in spirit of Gregg (2020) as the residual of a regression of sales on the number of workers and horsepower.[11]

Finally, the data report the different technologies employed at the firm-level. Thus, we directly identify firms that used either steam engines, water, or animal power or a combination.[12]

As the raw data do not contain an identifier to track firms over time, we use automatic record linkage algorithms (Ruggles, 2006) to link firms into a yearly panel. In a first step, we identify firms operating in the same region and industry. Among those firms we calculate so-called Jaro-Winkler and Levenshtein distances, which measure on a scale from zero to one how similar the names of the firms and their respective owners are. Highly similar observations are linked between years. We manually check the resulting panel and correct wrong links if necessary.

3.2 Identification of Corporations

A key aspect of our paper concerns the differential impact of adopting steam engines on firm-level outcomes given the organizational structure of firms. Specifically, we show that steam

[7]The Swedish name of the dataset is Fabriksberättelser. The National Board of Trade is also known as Kommerskollegium. See Appendix A.2 for examples of the underlying questionnaires.

[8]The industry is recorded as a string. To harmonize the data, we use the industrial classification developed in the national summaries in BiSOS D (SCB, 1910). Based on the respective string, we classify each firm as belonging to one industry. The different industries are shown in Appendix A.1. In the paper, we use the 12 aggregate industry codes. For about four percent of the data we have more than one industry recorded. In these cases, we only consider the primary industry of a firm.

[9]Sales include the value of inputs. We address this issue as described in the subsequent sections.

[10]The raw data report the tax paid by each firm. This rate was set at one percent of the respective profit (Kommerskollegium, 1919). Thereby we calculate firm-level profits.

[11]Formally, the regression is $lnSales_{it} = \beta_0 + \beta_1 lnWorker_{it} + \beta_2 lnHorsepower_{it} + \varepsilon_{it}$. Since horsepower is in many cases zero, the number of observations drops noticeably when using total factor productivity.

[12]Given the historical nature of our data, this reporting is not always consistent. Unless otherwise stated, we assume that a firm continues using a given technology after this is first recorded if that firm reports using the same technology in a later year. We define a set of dummies to measure which technology a given firm used. Thus, our results are more informative on the extensive margin.

engines and incorporation provided a key complementarity allowing firms to grow large. To substantiate this result and identify the underlying channels, we identify corporations and firms with related organizational structures according a set of definitions:

1. Two registers recorded all Swedish corporations that were founded between 1848 and 1881 (van der Hagen & Cederschiöld, 1875, 1882). From these registers we obtain the foundation year of a given corporation and match it to our factory data. We assume a firm remains incorporated after this is first recorded. Given that the last register was published in 1881, we cannot identify corporations that were founded afterwards. Thus, when using this definition we restrict the analysis to the period 1863-1881.

2. To identify corporations over the whole period of analysis 1863-1895, we additionally search the names of firms for evidence that they were incorporated. Names such as *Aktiebolag*, *AB* or *Limited* as well as alternative spellings are used to identify corporations. To be consistent, we search all years and define the year of incorporation as the first year where we find such information. We combine this information with definition 1. In case both definitions yield different years of incorporation, we take the earlier year. This is our preferred definition of corporations since it leverages all years in our data.

3. The data readily provide us with a dummy whether a firm is a company. These are known as *Bolag* in Swedish. While companies are not automatically corporations, they are clearly related concepts. We assume that a firm remains a company after this is first recorded. We call this variable *company* throughout the paper.

4. To better understand the underlying channels, we split the companies from definition 3 into two parts. First, we identify companies that were at any point corporations according to definition 2. We call these incorporated companies and contrast them in the regressions with family-owned firms. We call this variable *incorporated company* throughout the paper.

5. The remaining companies were never incorporated according to definition 2. We call them non-incorporated companies and contrast them similarly with family-owned firms. We call this variable *non-incorporated company* throughout the paper.

Our data corresponds well to the history of incorporation in Sweden as qualitatively sketched above. Appendices A.3 and A.4 show the yearly number of incorporations as well as the share of incorporated firms per industry. The rise in the number of incorporations until 1874, the following ten year slowdown as well as the subsequent growth are clearly visible. The share of incorporated firms was roughly similar across industries often reaching around 20 percent. The lowest number of incorporated firms was found in the textiles industries.

Figure A.5 shows the share of incorporated and non-incorporated companies by industry. About half of the companies from definition 3 are incorporated and non-incorporated. A general observation is that the share of incorporated companies matches the share of corporations quite closely. Given that these different definitions yield similar results, we are confident to correctly identify corporations in our data.

4 Adoption and diffusion of steam power

4.1 Descriptive and Regression Evidence

We begin by documenting the diffusion of steam engines among Swedish manufacturing plants 1863-1895 descriptively. Figure 1A displays the fraction of establishments in our data that reported using animal, steam, or water power. In conjunction with the descriptive evidence above, we observe that steam power gradually displaced water power as the major power source in Swedish manufacturing establishments. Simultaneously, the share of firms using no power source decreased. In the 1880s, steam power became the major power source.

We next disaggregate adoption by the organizational form of each plant. Here we separate out corporations. Figure 1B displays the share of (non-)incorporated plants that had adopted steam. Several stylized facts emerge suggesting that incorporation and the adoption of steam engines represent are complimentary: Corporations were more likely to use inanimate power throughout the period than non-incorporated plants. Especially steam power was used by corporations a larger extent. Steam engines were always the major power source of corporations whereas water power dominated until the 1880s in non-incorporated plants.

To examine the determinants of steam adoption more formally, we estimate regressions of the following form:

$$Y_t = \gamma + \mathbf{X}_t'\delta + \varepsilon_t \tag{1}$$

and

$$Y_{it} = \gamma + \mathbf{X}_{it}'\delta + \varepsilon_{it} \tag{2}$$

where Y is an indicator taking the value 1 if a plant i reports using a steam engine in year t. $\mathbf{X}$ is a vector of establishment-level covariates.

Tables 1 presents OLS estimates of Equation (1). Column 1 shows that an incorporated plant was about 34 percentage points more likely to use steam. We take this result as one motivation for arguing further below that there is a key complementarity between adopting a steam engine and incorporation. Next, we explore alternative explanations for steam engine adoption by adding control variables in the subsequent columns.

As argued above, a key virtue of the steam engine was that it released firms from the locational constraints imposed by water power. In line with such arguments, Rosenberg & Trajtenberg (2001) argue that the adoption of (Corliss) steam engines promoted urbanization in the United States.[13] We examine the association between urbanity and usage of steam power by defining an indicator taking the value 1 for establishments located in urban areas.[14] We find a weak link as being located in a city increases the likelihood of firms to adopt a steam engine by about 10 percentage points.

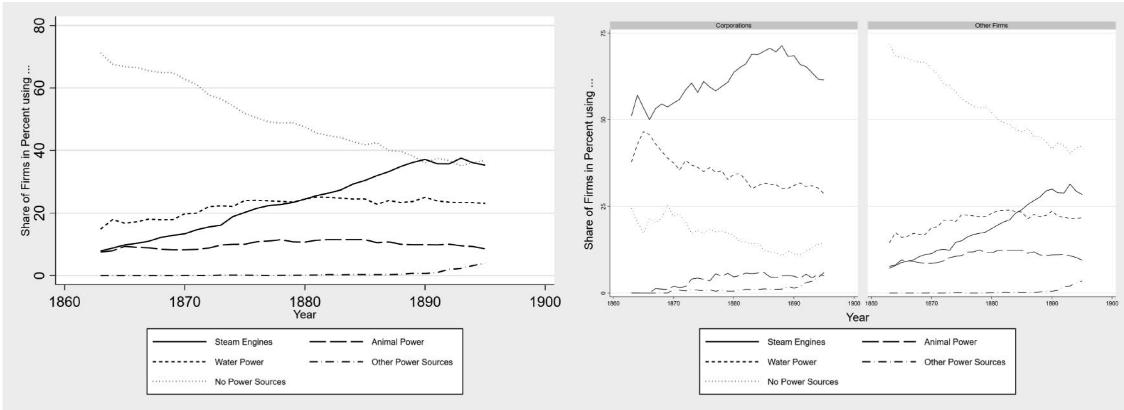
Atack et al. (2008) show that the adoption of steam engines was a crucial factor behind the growth of large-scale enterprises in the USA. They develop a model suggesting that the adoption of steam engines should increase in establishment size. This holds because a) steam engines increased the division of labor and b) the cost-advantages of using steam engines were positively related to the size of firms. In conjunction with this model, we also find that larger firms measured as the size of workers were more likely to install steam engines. Simultaneously, we observe a large drop in the coefficient for corporations. This suggests that part of the previously estimated positive impact of corporations on the adoption of steam engines is due to corporations being larger. Yet, the impact of corporations remains positive and statistically significant. We take this as support for our subsequent analysis on the complementarity between incorporation and usage of steam engines.

A further mechanism underlying the adoption of steam engines could be social learning. E.g. Conley & Udry (2010) document that farmers implement novel farming techniques after learning about their successful application by other farmers. We test the presence of such learning effects in a simpler framework by calculating the share of firms in a county using steam engines and relate that to the adoption of new steam engines by firms in the next period. Column (4) shows that increasing the share of firms using steam engines increases the chance that a firm adopts a steam engine in the next period. The effect appears larger within the same industries. This can be expected as firms are likely better connected within their industries. Learning about the deployment of new technologies should thus especially be present here. While statistically significant, the learning affects appear to be small however suggesting that it was not the main driver behind the diffusion of steam engines. Yet, there are many confounding variables. For example, we are not able to distinguish whether the previous adoption of steam engines was successful and we are restricted to the county-level.

Column (5) in Table 1 uses all independent variables simultaneously. Crucially, the coefficient for corporations remains positive and statistically significant. The city-dummy loses its statistical significance however. This suggests that the role of urban locations in driving the diffusion of steam engines should not be overstated. Columns (6)-(10) use as a robustness check companies defined according to definition 3 above instead of corporations as independent

[13]Kim (2005) revisits this question using plant-level data from the US manufacturing census showing that while workers in steam-using plants 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 19th century.

[14]We aggregate the data to the district level, which are known as *fögderi* in Swedish. We identify an urban region if the name of the fögderi contains the word *stad*, which is Swedish for *city*.



(A) ALL ESTABLISHMENTS (B) BY ORGANIZATIONAL FORM - CORPORATION

FIGURE 1: DIFFUSION OF STEAM POWER, 1863-1895.

Notes: This figure displays the share of establishments that reported using animal, steam, and/or water power in the *Fabriksberättelserna.* We use definition 2 for identifying corporations to leverage the full time dimension of our data.

variable. The results are highly similar strengthening the previous findings.

An alternative way to identify the importance of incorporation for adopting steam engines is to leverage the variation within firms according to Equation 2. Table 2 shows the corresponding results. Incorporation increases the likelihood of installing a steam engine by about 5 percentage points although again some of this effect is likely due to incorporated firms being larger. The results also remain robust when using focusing on companies rather than incorporation.

More crucially, the results suggest that the complementarity between organizational form and poiwer sources concerns only steam engines as the novel and superior technology of their time. Incorporation had to effect of the usage of water or animal power. If anything, it actually decreased the usage of animal power. These findings support the notion that incorporation was crucial for steam engines to become the dominant source of power as graphically shown by Figure 1.

4.2 Event Study Framework

A complementary way to identify the impact of incorporation on the adoption of steam is to leverage the temporal variation in an event study framework. We estimate:

$$Y_{it} = \gamma_i + \phi_{jt} + Corporation_i \sum_c \rho_c \mathbf{1}(C_{it} = c) + \mathbf{X}'_{it}\delta + \varepsilon_{it} \tag{3}$$

where Y again is an indicator capturing whether a an establishment i uses a steam engine in year t. We control for firm (γ_i) and industry-by-year (ϕ_{jt}) fixed effects. $\mathbf{1}(C_{it} = c)$ corresponds to a series of indicator variables taking the value 1 for 10 years before and after the year an

TABLE 1: DRIVERS OF ADOPTING A STEAM ENGINE - OLS

	(1) Steam Engine = 1	(2) Steam Engine = 1	(3) Steam Engine = 1	(4) Steam Engine = 1	(5) Steam Engine = 1	(6) Steam Engine = 1	(7) Steam Engine = 1	(8) Steam Engine = 1	(9) Steam Engine = 1	(10) Steam Engine = 1
Corporation = 1	0.340***	0.336***	0.084***	0.328***	0.090***					
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)					
	0.000	0.000	0.000	0.000	0.000					
Company = 1						0.210***	0.209***	0.039***	0.189***	0.030***
						(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
						0.000	0.000	0.000	0.000	0.000
City = 1		0.101***			0.005		0.107***			0.002
		(0.003)			(0.003)		(0.003)			(0.003)
		0.000			0.178		0.000			0.558
ln Workers			0.137***		0.127***			0.141***		0.133***
			(0.001)		(0.001)			(0.001)		(0.001)
			0.000		0.000			0.000		0.000
Lag Share Same Industry using Steam = 1				0.005***	0.003***				0.005***	0.003***
				(0.000)	(0.000)				(0.000)	(0.000)
				0.000	0.000				0.000	0.000
Lag Share Others using Steam = 1				0.004***	0.001***				0.004***	0.001***
				(0.000)	(0.000)				(0.000)	(0.000)
				0.000	0.000				0.000	0.000
R-Squared	0.200	0.210	0.339	0.261	0.372	0.183	0.195	0.338	0.241	0.371
Number of Observations	101,104	101,104	88,995	77,122	68,172	101,408	101,408	89,259	77,376	68,389
Mean Dependent Variable	0.253	0.253	0.277	0.248	0.272	0.254	0.254	0.278	0.249	0.273
Firm FE	No	No	No	No	No	No	No	No	No	No
Industry by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: We use definition 2 for identifying corporations to leverage the full time dimension of our data. Definition 3 is used to identify companies. In specifications (6)-(7) we exclude firms switching industries. Robust standard errors are given in parentheses. The p-values are stated below and their levels of significance are *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

TABLE 2: INCORPORATION AND ADOPTING DIFFERENT POWER SOURCES - FE

	(1) Steam Engine = 1	(2) Steam Engine = 1	(3) Water Power = 1	(4) Animal Power = 1	(5) Steam Engine = 1	(6) Steam Engine = 1	(7) Water Power = 1	(8) Animal Power = 1
Corporation = 1	0.049***	0.020	0.011	-0.015				
	(0.018)	(0.017)	(0.011)	(0.011)				
	0.007	0.259	0.290	0.165				
Company = 1					0.026***	0.019*	0.010	-0.009
					(0.009)	(0.010)	(0.007)	(0.006)
					0.005	0.051	0.143	0.158
ln Workers		0.064***				0.064***		
		(0.005)				(0.005)		
		0.000				0.000		
Within R-Squared	0.001	0.020	0.000	0.000	0.001	0.021	0.000	0.000
Number of Observations	98,039	86,202	98,039	98,039	98,340	86,463	98,340	98,340
Number of Firms	10,137	9,221	10,137	10,137	10,151	9,234	10,151	10,151
Mean Dependent Variable	0.254	0.279	0.226	0.100	0.256	0.280	0.226	0.100
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: We use definition 2 for identifying corporations to leverage the full time dimension of our data. Definition 3 is used to identify companies. Cluster-robust standard errors at the firm-level are given in parentheses. The p-values are stated below and their levels of significance are *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

establishment is incorporated (c).[15]

Figure 2 displays estimates and 95% confidence intervals from Equation (3). In the years prior to incorporation, there are no significant differences in the use of steam engines. However, after an establishment is incorporated, there is a sharp jump in the probability that a plant uses steam. Notably, this increase is relatively stable in the following years after incorporation suggesting that many establishments incorporated and invested in steam technology jointly in

[15] We use Stata throughout the whole paper. We estimate all event studies using the *eventdd*-command by Clarke & Schythe (2020).

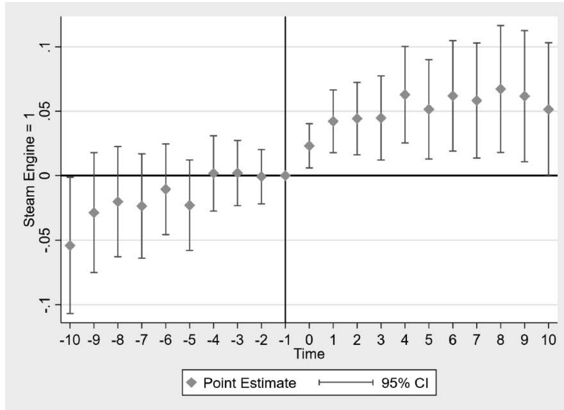


FIGURE 2: EFFECT OF INCORPORATION ON THE ADOPTION OF STEAM ENGINES, 1863-1895

Notes: We use definition 2 for identifying corporations to leverage the full time dimension of our data. We control for firm, industry-year, industry-region and city FE. We use multiway cluster-robust standard errors at the firm-, industry-year- and region-year-levels.

the same year.

5 The Firm-Level Impact of Adopting Steam

The previous section documented that steam engines became the dominant source of power in Sweden during the 1880s and that incorporation went hand in hand with the adoption of steam engines. This section estimates the firm-level impact of adopting a steam engine both in a regression and event study framework and documents how incorporation allowed firms to grow large through using steam power.

5.1 Average impact

To identify the impact of steam on establishment-level outcomes, we take a difference in differences approach comparing relative differences in an outcome Y_{it} among (non-)adopting plants before and after adoption:

$$Y_{it} = \gamma_i + \phi_{jt} + \beta Steam_{it} + \mathbf{X}'_{it}\delta + \varepsilon_{it} \tag{4}$$

Here $Steam$ corresponds to an indicator taking the value 1 if an establishment i used at least one steam engine by year t. **X** is a vector of firm-level controls. Table 3 reports estimates of Equation (4). For comparison with the extant literature (Atack et al., 2008), we report simple OLS estimates excluding firm-level fixed effects (Panel A), as well as estimates including firm-level fixed effects (Panel B). We estimate the impact of adopting a steam engine on a variety of firm-level outcomes including total employment and employment disaggregated by gender, sales, profits, and productivity.

Panel A reports the results from estimating Equation (4) without firm-level fixed effects. The results show the difference in outcomes between firms that used steam engines and firms that did not. We observe that steam-using firms were larger in terms of workers, sales, and profits. They also had higher labor and total factor productivity. Steam-using firms employment more men, women, and children. More interesting, the share of women in the workforce was higher in firms using steam engines while the share of children was lower. Yet, these results cannot be interpreted as the causal contribution of adopting steam engines to firm-level outcomes. One difficulty is that larger firms might have simply been more likely to install steam engines in the first place. We address this issue by including firm-level fixed effects in the regression.

Panel B shows shows the results from estimating Equation (4) in a panel setting. Including firm-level fixed effects overall reduces the size of the coefficients suggesting that unobserved time-invariant factors at the firm-level are important to account for. The interpretation also changes. Now, the coefficients measure the average change a firm experiences in an outcome when that firm adopts a steam engine. A first key observation in Panel B is that the size of firms expanded after the adoption of a steam engine. When measuring the size of firms in terms of employment, we see that the adoption of a steam engine increases the total number of workers at a firm by about 37 percent or 32 log points. This is an economically as well as statistically significant effect.

A similar picture emerges when measuring the size of firms in terms of their output. In terms of total sales, we attribute a relative increase of about 55 percent or 44 log points to the adoption of steam engines. A confounding factor could be that the sales include the value of inputs. However, the firm fixed effects should account for this issue if the share of inputs stays constant within firms and industries over time. Alternatively, we also observe that firms expanded increased their profits due the adoption of a steam engine by 40 percent or 34 log points. Taken together, these results suggest that adopting steam engines played a crucial role for firms to grow large measured either in terms of workers, sales or profits.

Figure 3 visualizes these estimations in a similar event study framework as above. Again, we observe a rise in the number of workers and firm-level output following the adoption of a steam engine. This increase remains largely stable over the following years suggesting that the estimated effect was permanent.

Using our data, we are also able to construct different measures of firm-level productivity. Specifically, we divide sales and profits by the number of workers to estimate a measure of labor productivity. As described in Section 3, we can also estimate a measure of total factor productivity TFP. The results are quite consistent suggesting the adoption of a steam engine on average increased firm-level productivity by about 10 percent. This is in line with the historical background in Section 2. However, we do not regard the positive impact on productivity of adopting steam as our key results for reasons discussed in Section 5.2. Consistent with our focus, we note that the impact on productivity measured as $ln(Profits/Workers)$ is much smaller and (almost) statistically insignificant. Overall, we emphasize the role of the steam engine in allowing firms to grow large rather than improving their efficiency.

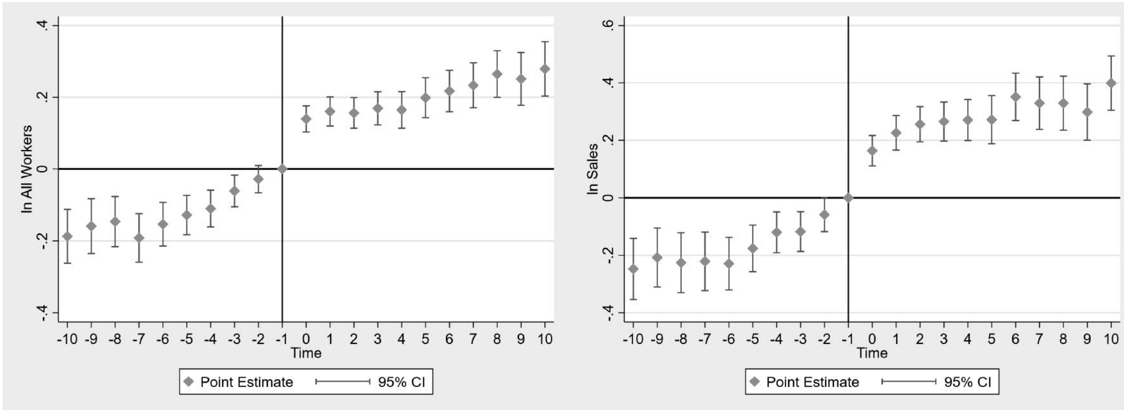
Industrialization changed in many ways how people and especially women worked (Burnette, 2008). Women increasingly became part of the industrial workforce accounting in Sweden for around 30 percent of it by 1870. However, there was a substantial variation across industries. Women represented the majority of workers in textiles but few of them worked in metal, wood, and engineering industries. The female share of the workforce in other industries laid in between (Schön, 2012).

Traditionally, women were employed as assistants to male workers at the factories. However, the advent of new machinery powered e.g. by steam engines changed these relationships and women increasingly took over machine operations. Given that women were on average paid less than men, this represented a substantial cost reduction for factory owners. Mechanization also led to a reduction in child labor. With mechanization, the tasks in operating the machines became more complex and children were not suited for that. Thus, child labor was already on the decline in factories before it was eventually legally banned. Yet, it remained present in more rural and non-mechanized operations Schön (2012).

While this represents the overall development of female and child labor during the industrialization of Sweden (Schön, 2012), we can underpin these developments with some concrete quantitative evidence using our detailed firm-level data. In columns (7)-(11), we find that adopting a steam engine led to an increase in all types of employment, i.e. male, female, and child labor increased. However, we also find that adopting steam power increased the share of the female workforce while it had no impact on the share of child labor within firms. In light of the aggregate developments as sketched above, we thus attribute an increasing feminization of the workforce at the firm-level to the adoption of steam engines.[16]

Lastly, we note two broader implications in relation to the previous literature. First, we find that adopting a steam engine increased the likelihood for firms to become factories, which are defined as plants with 16 or more employees following Atack et al. (2008). We do not use this definition however any further as we can readily identify different types of factories as outlined in Section 3. Yet, this observation reaffirms our finding that adopting steam power led to an increase in the size of firms. Second, we can define a dummy for the last year a given firm is in operation. Using this dummy as outcome, we observe that adopting steam engines decreased the likelihood of firm exit. Thus, we note that there are also broader effects of technology adoption beyond the mere impact on the output of firms.

[16]The finding that the coefficient for $ln\ Men$ is larger than the one for $ln\ Women$ while the coefficient for $Share\ Women$ is also large and statistically significant is somewhat surprising. However, some part of this contradiction is due to the lower share of women employed at firms. Thus, we calculate $ln\ Men$, $ln\ Women$, and $ln\ Children$ by using the transformation $ln(1 + x)$ where x represents the variable of interest. However, we do not use this transformation when calculating the shares. The coefficient for male employment decreases substantially when including only observations with a strictly positive number of female employees. As such, we believe that the coefficients for $Share\ Women$ and $Share\ Children$ are more accurate as they contain all observations and do not use the transformation described above.



(A) LN ALL WORKERS (B) LN SALES

FIGURE 3: ADOPTION OF STEAM AND PLANT-LEVEL OUTCOMES, 1863-1895

Notes: The underlying regressions are based on Table 3 using the fixed-effects regressions at the firm-level. Here, we assume a firm continues using a steam engine in all years after it is first reported.

After having established that steam engines led to a statistically and economically significant expansion in firm size, we next turn to examine one channel potentially underlying these results. Specifically, we test our second hypothesis that the steam engine and incorporation represented a key complementarity allowing firms to adopt steam power and consequentially grow large.

TABLE 3: IMPACT OF ADOPTING A STEAM ENGINE - OLS (TOP) AND FE (BOTTOM)

	(1) ln All Workers	(2) ln Sales	(3) ln(Sales / Workers)	(4) TFP	(5) ln Profits	(6) ln(Profits / Workers)	(7) ln Men	(8) ln Women	(9) ln Children	(10) Share Women	(11) Share Children	(12) Factory = 1	(13) Firm Exit
Steam Engine = 1	1.509***	2.312***	0.610***	0.015**	1.706***	0.135***	1.399***	0.698***	0.665***	4.443***	-0.886***	0.417***	-0.049***
	(0.011)	(0.015)	(0.008)	(0.007)	(0.014)	(0.010)	(0.009)	(0.010)	(0.009)	(0.193)	(0.141)	(0.004)	(0.002)
	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R-Squared	0.387	0.345	0.227	0.000	0.319	0.143	0.365	0.179	0.205	0.136	0.070	0.291	0.061
Number of Observations	89,259	93,566	85,018	32,100	72,703	67,108	101,408	101,408	101,408	84,590	85,890	89,259	101,408
Firm FE	No	No	No	No	No	No	No	No	No	No	No	No	No
Industry by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	(1) ln All Workers	(2) ln Sales	(3) ln(Sales / Workers)	(4) TFP	(5) ln Profits	(6) ln(Profits / Workers)	(7) ln Men	(8) ln Women	(9) ln Children	(10) Share Women	(11) Share Children	(12) Factory = 1	(13) Firm Exit
Steam Engine = 1	0.320***	0.442***	0.113***	0.103***	0.342***	0.037	0.339***	0.158***	0.152***	1.256***	-0.005	0.104***	-0.059***
	(0.022)	(0.032)	(0.021)	(0.033)	(0.028)	(0.025)	(0.024)	(0.022)	(0.022)	(0.424)	(0.378)	(0.010)	(0.005)
	0.000	0.000	0.000	0.002	0.000	0.141	0.000	0.000	0.000	0.003	0.989	0.000	0.000
Within R-Squared	0.021	0.015	0.001	0.001	0.011	0.000	0.015	0.005	0.004	0.000	0.000	0.011	0.002
Number of Observations	86,463	90,970	82,461	32,100	70,107	64,679	98,340	98,340	98,340	81,972	83,251	86,463	98,340
Number of Firms	9,234	9,423	8,831	3,922	7,965	7,430	10,151	10,151	10,151	8,836	8,925	9,234	10,151
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Please refer to section 3 for details on the construction of the variables. In addition, a factory is a firm with 16 or more employees as defined by Atack et al. (2008). We calculate $ln\ Men$, $ln\ Women$, and $ln\ Children$ as $ln(1+x)$ where x represents the variable of interest given that there was often no female employment at a factory. The variables $ln\ Men$, $ln\ Women$, and $Share\ Women$ contain men and women aged 18 years or older that are either registered at or external a given firm. To calculate the variable $Share\ Women$, we calculate the total number of workers at the factory as the sum of male and female workers. $ln\ Children$ contains boys and girls below 18 working at the firm. We do not know whether they are directly employed by or external to the firm. We add this number to the total number of workers at the firm when calculating the variable $Share\ Children$. All shares are measured on a scale of 0 to 100. Cluster-robust standard errors at the firm-level are given in parentheses. We use robust standard errors for the OLS regressions. The p-values are stated below and their levels of significance are *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

5.2 Complementarities between institutional and technological change: the heterogeneous impact of steam

The previous sections document a) how incorporation increased the likelihood of firms to adopt steam engines and b) that adopting a steam engine allowed firms to grow large. In this section, we document that incorporation and the adoption of steam engines represent a key complementarity: To reap the full advantages of steam power, firms chose to incorporate in order to reduce risk and obtain enough capital to finance its installation. We test our hypothesis using the following regression:

$$Y_{it} = \gamma_i + \phi_{jt} + \beta Steam_{it} + \rho Corp_{it} + \sigma(Steam_{it} \times Corp_{it}) + \mathbf{X}'_{it}\delta + \varepsilon_{it} \quad (5)$$

We expect the same coefficients as above for β. Given our hypothesis that steam engines had larger effects in corporations, we expect to find large statistically significant results for σ. Similar to the above analysis, we estimate Equation 5 both with and without firm-level fixed effects. Panels A and B in Table 4 show the results. To leverage the full time dimension of our data, we use definition 2 for corporations. We later show that the results remain robust when using a different definition.

We regard Column (1) in Panel B of Table 4 as our key result. It suggests that adopting a steam engine allowed especially corporations to grow large. The positive and statistically significant interaction term suggests that adopting a steam engine increased firm-level size measured as the number of workers by about 9 percent more for corporations compared to sole proprietorships. This result is reinforced when using $ln(Sales)$ as outcome.[17]

The subsequent regressions suggest that the expansion in total employment is mainly driven by the increase in male employment. After incorporation, we observe a decrease in the share of women in the workforce with the adoption of a steam engine. Schön (2012) discusses multiple instances where male workers objected to the hire of female workers due to fears of a hollowing out of their profession. It is possible that such factors were more important in corporations than in smaller businesses, which supports these results.[18]

While we attribute growth in the size of firms to the adoption of steam engines and incorporation, are the effects on productivity more complicated. Given that adopting a steam engine increases the available capital per worker, should labor productivity automatically increase (Atack et al., 2008). However, incorporation can also lead to more administration within firms. This has a productivity-decreasing effect. The net effect on total factor productivity can thus be positive or negative. If it is sufficiently negative, it is possible that labor productivity is not or even negatively impacted (Gregg, 2020).

[17] While this effect is statistically insignificant, we observe statistically significant effects for sales as outcome variable when using different definitions of corporations (Table 5).

[18] Two ancillary results that we do not interpret further are that the share of children was unaffected by the adoption of steam engines in corporations as well and that adopting a steam engine did not lower the risk of exit for especially corporations.

Such ambiguity likely underlies our estimated interaction coefficients for productivity. While we do not find a statistically significant impact when defining productivity as $ln(Sales/Workers)$, the effect is negative and statistically significant when using $ln(Profits/Workers)$ as a definition. The observation that the coefficient for total factor productivity is also negative albeit insignificant is consistent with these findings. Given this ambiguity, we stress that the adoption of steam engines and incorporation mainly allowed firms to grow larger without necessarily becoming more productive.

Next, we show in Table 5 that the stronger results for corporations are indeed driven by the advantages of incorporating instead of confounding factors. As we have established that adopting a steam engine increased mainly the size of firms, we focus on $ln\ All\ Workers$ and $ln\ Sales$ as outcome variables. To substantiate our results, we first use definition 1 instead of definition 2 as outlined in Section 3 for identifying corporations in our data. Columns 1 and 6 show the results whereas columns (2) and (8) replicate the previous results using definition 2 for ease of comparison. While the benefit of definition 1 is that we do not have to identify corporations from the names of firms, its downside is that it is available only for years before 1882. As such, we prefer definition 2. Still, using definition 1 we observe statistically significant and even larger effects compared to using definition 2. This strengthens our confidence in the previous results.

As a second robustness check, we compare the effect of adopting a steam engine across different types of business organizations. When doing so, we only observe a larger impact in corporations. Thus, we can argue that the advantages attributed to corporations are indeed driving the findings. This argument relies on a key feature of our data. Specifically, the data contain a dummy for whether a given firm was a company or a sole proprietorship. This dummy corresponds to definition 3 from Section 3 and is somewhat loosely defined as corporations or partnerships are both considered companies. On a side note, it is reassuring that using this dummy for the interaction produces again a statistically significant and even slightly larger effect (Columns 3 and 9).

More crucially, we can use our definition 2 for corporations and combine it with the dummy for companies. Thereby we can identify companies that were at any time incorporated. As such, we can contrast incorporated companies (definition 4) and non-incorporated companies (definition 5) with sole proprietorships. The idea of this exercise is that both incorporated and non-incorporated companies should have been similar in many respects. For example, both types of companies had likely some kind of formal management and should arguably be more open to employing novel technologies in comparison to sole proprietorships.

However, the decisive difference between both organizational forms is that corporations were a novel organizational form with limited liability. As outlined above, this should have reduced their risk in installing steam engines and improved their access to capital. Thus, if we observe a stronger interaction when contrasting incorporated companies with sole proprietorships compared to contrasting non-incorporated companies with sole proprietorships, this would be strong evidence that the key difference between both organizational types matters. Columns (4-5) and (10-11) show that the interaction effects are indeed larger and statistically significant for incorporated companies. In contrast, they are smaller and insignificant for non-incorporated companies.[19]

Thus, we are confident that the process of incorporation as institutional innovation is underlying our findings. In general, steam engines allowed firms to grow large. However, our results suggest that incorporation represented a key complimentarity to this process. Incorporation and the adoption of steam occured simultaneously. To reap the benefits of steam power, firms chose to incorporate. Given their improved access to capital and lower risks, they could install steam engines to grow larger even than their steam-using competitors.

[19]Additionally, we rule out firm size as a potential explanation. Similarly to Atack et al. (2008), we define factories as firms with 16 or more employees. However, we do not find a similar positive and statistically significant interaction term in this regression.

TABLE 4: IMPACT OF ADOPTING A STEAM ENGINE FOR CORPORATIONS - OLS (TOP) AND FE (BOTTOM)

	(1) ln All Workers	(2) ln Sales	(3) ln(Sales / Workers)	(4) TFP	(5) ln Profits	(6) ln(Profits / Workers)	(7) ln Men	(8) ln Women	(9) ln Children	(10) Share Women	(11) Share Children	(12) Firm Exit
Steam Engine = 1	1.254***	2.015***	0.560***	0.014*	1.503***	0.159***	1.166***	0.505***	0.492***	3.249***	-1.153***	-0.046***
	(0.011)	(0.016)	(0.010)	(0.008)	(0.014)	(0.011)	(0.010)	(0.010)	(0.009)	(0.219)	(0.162)	(0.002)
	0.000	0.000	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Corporation = 1	1.408***	2.175***	0.596***	0.009	1.541***	-0.026	1.124***	0.717***	0.734***	6.614***	1.298***	-0.031***
	(0.022)	(0.032)	(0.017)	(0.014)	(0.030)	(0.023)	(0.020)	(0.020)	(0.020)	(0.377)	(0.290)	(0.004)
	0.000	0.000	0.000	0.542	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000
Steam Engine * Corporation = 1	-0.108***	-0.530***	-0.234***	-0.001	-0.391***	-0.061**	-0.003	0.125***	0.057**	-0.604	-0.092	0.013**
	(0.028)	(0.039)	(0.021)	(0.016)	(0.038)	(0.028)	(0.027)	(0.028)	(0.027)	(0.482)	(0.351)	(0.005)
	0.000	0.000	0.000	0.956	0.000	0.033	0.916	0.000	0.034	0.211	0.793	0.017
R-Squared	0.467	0.413	0.242	0.000	0.369	0.143	0.434	0.233	0.261	0.142	0.070	0.062
Number of Observations	88,995	93,294	84,764	31,932	72,491	66,897	101,104	101,104	101,104	84,328	85,626	101,104
Firm FE	No	No	No	No	No	No	No	No	No	No	No	No
Industry by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	(1) ln All Workers	(2) ln Sales	(3) ln(Sales / Workers)	(4) TFP	(5) ln Profits	(6) ln(Profits / Workers)	(7) ln Men	(8) ln Women	(9) ln Children	(10) Share Women	(11) Share Children	(12) Firm Exit
Steam Engine = 1	0.295***	0.419***	0.114***	0.105***	0.344***	0.056**	0.305***	0.146***	0.122***	1.565***	-0.123	-0.056***
	(0.023)	(0.033)	(0.023)	(0.038)	(0.028)	(0.026)	(0.023)	(0.020)	(0.022)	(0.455)	(0.414)	(0.005)
	0.000	0.000	0.000	0.005	0.000	0.032	0.000	0.000	0.000	0.001	0.766	0.000
Corporation = 1	0.228***	0.286***	0.024	0.091	0.252***	-0.056	0.182***	0.229***	0.120**	2.483***	-1.019	-0.007
	(0.047)	(0.070)	(0.047)	(0.058)	(0.075)	(0.064)	(0.052)	(0.056)	(0.053)	(0.894)	(0.807)	(0.010)
	0.000	0.000	0.614	0.116	0.001	0.382	0.000	0.000	0.024	0.005	0.207	0.506
Steam Engine * Corporation = 1	0.086*	0.077	0.003	-0.019	-0.072	-0.102*	0.127**	0.021	0.131**	-1.713**	0.811	-0.013
	(0.046)	(0.066)	(0.044)	(0.055)	(0.068)	(0.062)	(0.056)	(0.056)	(0.056)	(0.844)	(0.745)	(0.010)
	0.060	0.248	0.949	0.735	0.290	0.097	0.024	0.700	0.019	0.042	0.277	0.211
Within R-Squared	0.028	0.018	0.001	0.002	0.012	0.001	0.019	0.009	0.007	0.001	0.000	0.002
Number of Observations	86,202	90,701	82,210	31,932	69,896	64,469	98,039	98,039	98,039	81,713	82,990	98,039
Number of Firms	9,221	9,409	8,818	3,911	7,952	7,417	10,137	10,137	10,137	8,823	8,912	10,137
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Please refer to Table 3 and section 3 for details on the construction of the variables. Cluster-robust standard errors at the firm-level are given in parentheses. We use robust standard errors for the OLS regressions. We use definition 2 for identifying corporations to leverage the full time dimension of our data. The p-values are stated below and their levels of significance are *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. We use definition 2 for corporations.

TABLE 5: IMPACT OF ADOPTING A STEAM ENGINE BY DIFFERENT OWNERSHIP TYPES - FIXED EFFECTS

	ln All Workers						ln Sales					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Steam Engine = 1	0.296***	0.295***	0.260***	0.275***	0.267***	0.224***	0.415***	0.419***	0.386***	0.373***	0.391***	0.362***
	(0.031)	(0.023)	(0.024)	(0.029)	(0.024)	(0.021)	(0.045)	(0.033)	(0.036)	(0.044)	(0.040)	(0.035)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Corporation = 1	0.239***	0.228***					0.250***	0.286***				
	(0.057)	(0.047)					(0.091)	(0.070)				
	0.000	0.000					0.006	0.000				
Steam Engine * Corporation = 1	0.127**	0.086*					0.184*	0.077				
	(0.060)	(0.046)					(0.101)	(0.066)				
	0.034	0.060					0.067	0.248				
Company = 1			0.064***						0.114***			
			(0.024)						(0.037)			
			0.007						0.002			
Steam Engine * Company = 1			0.124***						0.115**			
			(0.031)						(0.045)			
			0.000						0.011			
Incorporated Company = 1				0.226***						0.315***		
				(0.062)						(0.090)		
				0.000						0.000		
Steam Engine * Incorporated Company = 1				0.139***						0.165**		
				(0.051)						(0.075)		
				0.007						0.029		
Non-Incorporated Company = 1					0.058**						0.096**	
					(0.023)						(0.038)	
					0.011						0.012	
Steam Engine * Non-Incorporated Company = 1					0.036						0.005	
					(0.037)						(0.054)	
					0.333						0.926	
Factory = 1						0.937***						0.762***
						(0.025)						(0.037)
						0.000						0.000
Steam Engine * Factory = 1						-0.004						-0.019
						(0.030)						(0.043)
						0.906						0.649
Within R-Squared	0.023	0.028	0.024	0.031	0.016	0.187	0.015	0.018	0.017	0.020	0.011	0.059
Number of Observations	41,724	86,202	86,463	64,601	68,924	86,463	45,212	90,701	90,970	68,900	73,844	82,461
Number of Firms	5,275	9,221	9,234	7,190	7,754	9,234	5,494	9,409	9,423	7,384	7,969	8,831
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry by Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Cluster-robust standard errors at the firm-level are given in parentheses. A factory is a firm with 16 or more employees as defined by Atack et al. (2008). The p-values are stated below and their levels of significance are *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. We use definition 1 of corporations in columns (1) and (7) and definition 2 in columns (2) and (8). Section 3 provides more details on these definitions.

6 Conclusions

This paper analyzes the adoption and impact of steam technology on firm-level outcomes. We leverage novel yearly establishment-level data covering the entire Swedish manufacturing industry in the latter half of the 19th-century. We provide three key results. First, we document descriptively the diffusion of steam power across firms and discuss the relative importance of various underlying drivers including incorporation, social learning, urbanization, and firm size. Second, difference in differences and event study estimates show that the adoption of steam engines raised firm size, output, and labor productivity significantly. For example, adopting a steam engine increased the number of workers at a firm by 37 percent. While both male and female employment expanded, we observe a significant increase in the share of women in the workforce. The share of children in the workforce was unaffected however. Third, we provide evidence of a key complementarity between institutional and technological change: Incorporation raised the probability of adopting steam and incorporated plants grew significantly larger after adoption. We argue that incorporation lowered the risk for firms to install steam engines and improved their access to capital because they operated now under limited liability. More broadly, these results shed light on the complementarities between institutional and technological change: Organizational innovation were required to reap the full benefits of the new technology of steam engines.

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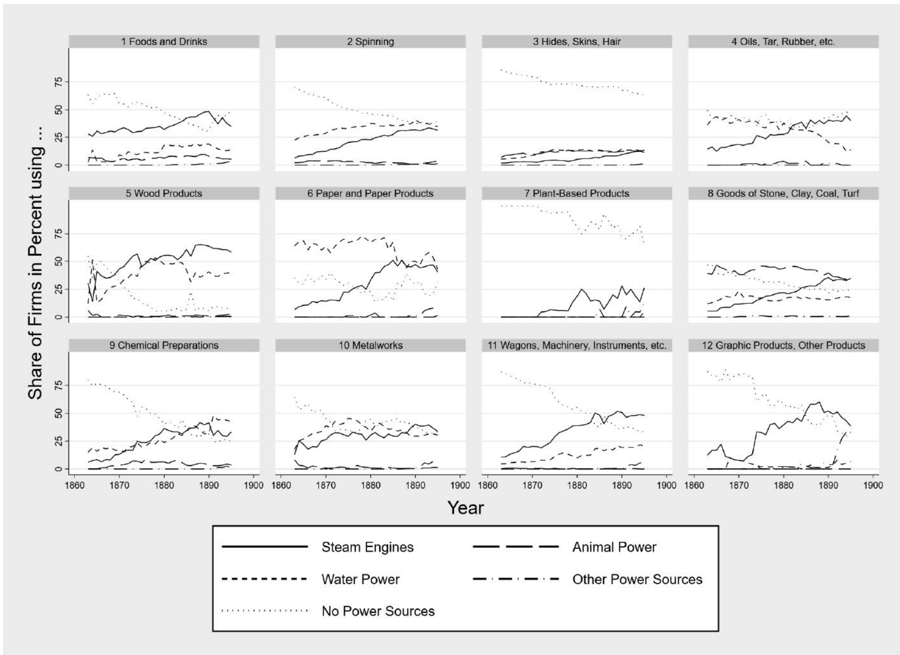
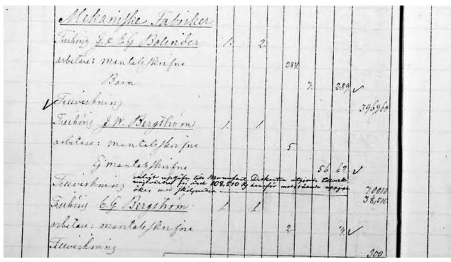
Appendix

FIGURE A.1: DIFFUSION OF STEAM POWER BY INDUSTRY, 1863-1895

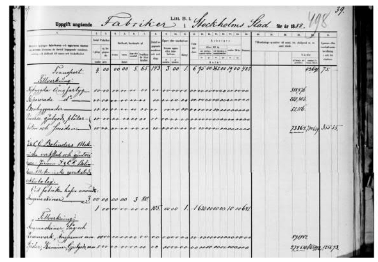


Notes: We assume that a firm uses any power source in years where this is not reported if that firm uses that power source in any prior and subsequent year.

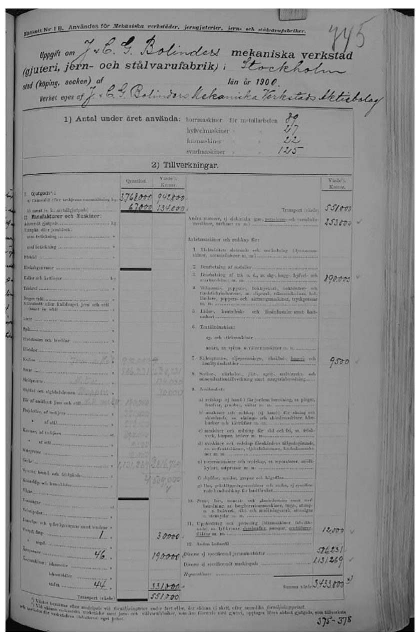
FIGURE A.2: THE QUESTIONNAIRES SEND TO BOLINDERS MEKANISKA VERKSTAD IN VARIOUS YEARS



1860



1888

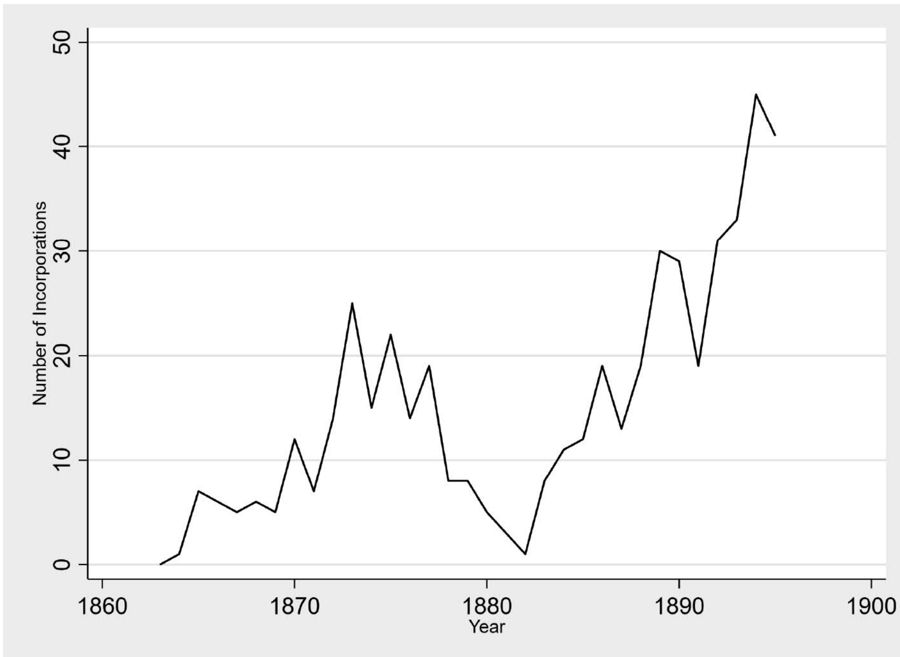


1890

TABLE A.1: THE INDUSTRY CODES USED IN THE FABRIKSBERÄTTELSER

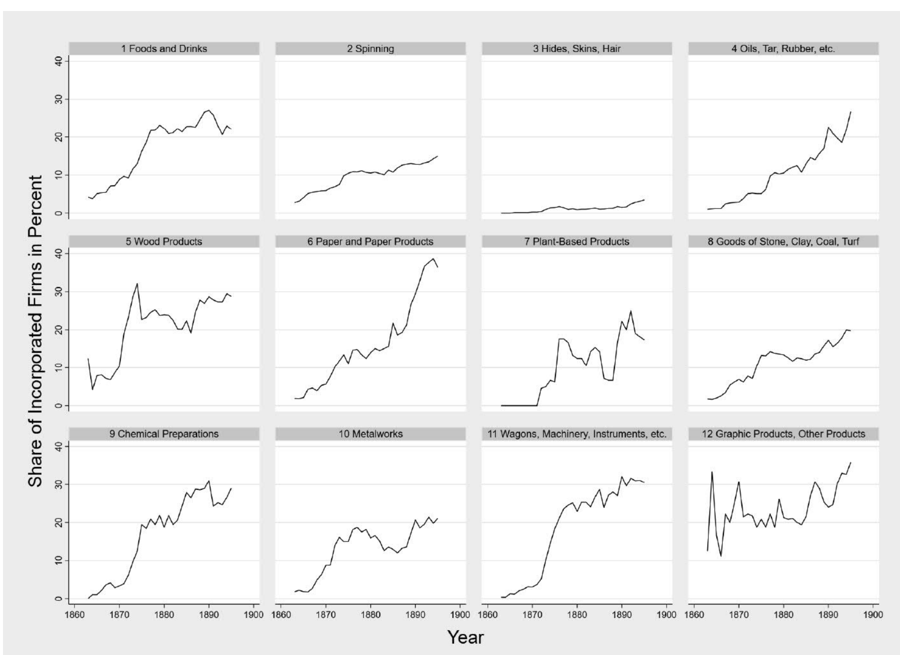
Industry	1900 Subindustry Code	1900 Subindustry Code Numerical	1900 Industry Code Aggregated	Description Industry Code Aggregated
Animal Products	1_a	1011	1	Foods and Drinks
Products of Cereal and Root	1_b	1012	1	Foods and Drinks
Sugar, Chocolate, Tobacco and Coffee	1_c	1013	1	Foods and Drinks
Alcohol, Drinks and Vinegar	1_d	1014	1	Foods and Drinks
Yarn, Thread and Rope	2_a	1021	2	Spinning
Weaving	2_b	1022	2	Spinning
Textile Finishing	2_c	1023	2	Spinning
Clothing and other Textile Products	2_d	1024	2	Spinning
Leather and Hide Processing	3_a	1031	3	Hides, Skins, Hair
Products Leather, Hide and Hair	3_b	1032	3	Hides, Skins, Hair
Tallow, Oils, Tar and Resin	4_a	1041	4	Oils, Tar, Rubber, etc.
Products of Tallow, Oils, Tar and Resin	4_b	1042	4	Oils, Tar, Rubber, etc.
Sawed and Planed Wood	5_a	1051	5	Wood Products
Wooden Products	5_b	1052	5	Wood Products
Paper and Cardboard	6_a	1061	6	Paper and Paper Products
Products of Paper and Cardboard	6_b	1062	6	Paper and Paper Products
Plant Products	7	1070	7	Plant-Based Products
Products of Stone and Clay	8_a	1081	8	Goods of Stone, Clay, Coal, Turf
Glass and Products of Glass	8_b	1082	8	Goods of Stone, Clay, Coal, Turf
Products of Coal and Peat	8_c	1083	8	Goods of Stone, Clay, Coal, Turf
Inorganic Acids, Bases and Salts	9_a	1091	9	Chemical Preparations
Fertilizers	9_b	1092	9	Chemical Preparations
Explosives	9_c	1093	9	Chemical Preparations
Colors and other Chemical Products	9_d	1094	9	Chemical Preparations
Metal and Steel Work	10_a	1101	10	Metalworks
Other Metals	10_b	1102	10	Metalworks
Ships and Boats	11_a	1111	11	Wagons, Machinery, Instruments, etc.
Wagons and other Vehicles	11_b	1112	11	Wagons, Machinery, Instruments, etc.
Machines and Tools	11_c	1113	11	Wagons, Machinery, Instruments, etc.
Instruments	11_d	1114	11	Wagons, Machinery, Instruments, etc.
Clocks	11_e	1115	11	Wagons, Machinery, Instruments, etc.
Graphic Products and Others	12	1120	12	Graphic Products, Other Products

FIGURE A.3: NUMBER OF INCORPORATIONS, 1863-1895



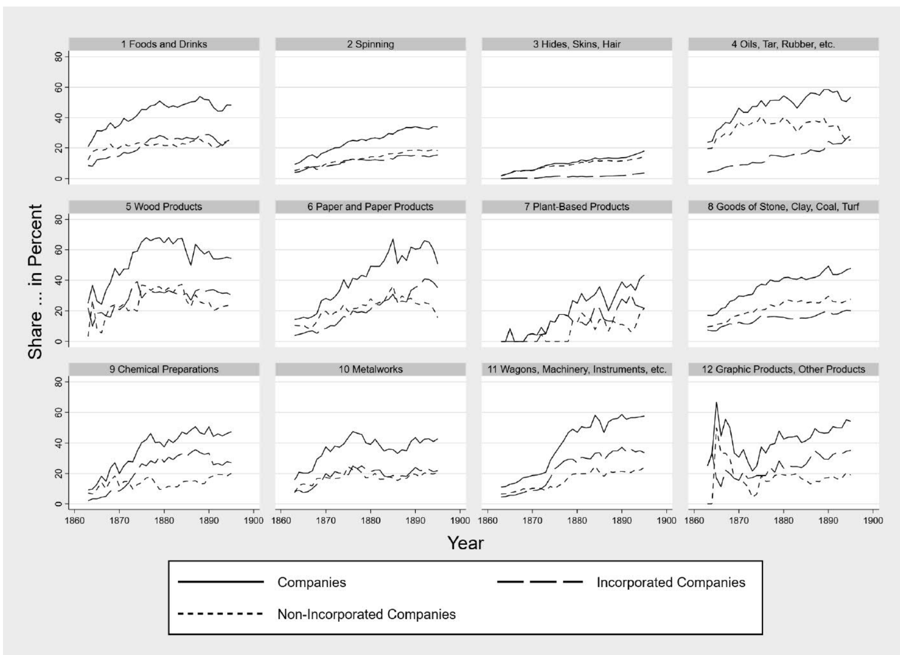
Notes: We use definition 2 to identify corporations in this figure.

FIGURE A.4: SHARE OF INCORPORATED FIRMS BY INDUSTRY, 1863-1895



Notes: We use definition 2 to identify corporations in this figure.

FIGURE A.5: SHARE OF ACTIVE COMPANIES BY TYPE OF OWNERSHIP AND INDUSTRY, 1863-1895



Notes: Companies refer to definition 3. Incorporated companies refer to definition 4 and non-incorporated companies to definition 5.