Deskilling: Firm Evidence from Europe and the United States*

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Abstract

Technological change raised the demand for skilled workers over the past century, but is believed to have reduced the demand for skills during the industrial revolution. I use census data covering half a million industrial firms in Europe and the United States to show that deskilling was pervasive: the rise of the factory was associated with a relative shift toward unskilled workers—women and children—in all countries and within virtually all industries. Yet the main driver of deskilling was not mechanization: firms using inanimate power employed relatively fewer unskilled workers, suggesting that the driver of deskilling may have been organizational rather than technological changes and that the origins of skill-biased technological change may be traced to the shift from hand to inanimate power in the nineteenth century.

Keywords: Deskilling; human capital; industrialization; technological change
JEL Codes: J24; O33; N60

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1 Introduction

Technological change has increased the relative demand for skilled workers over the past century (Goldin and Katz, 2008), a process led by large firms adopting new technologies and organizational practices (Atack et al., 2008; Engbom et al., 2025; Nicholas, 2026). In the nineteenth century, large firms likewise spearheaded technological and organizational change (Chandler, 1977). Yet contemporaries believed that the rise of the large factory led to deskilling, as skilled artisans were displaced by unskilled workers and machinery (Allen, 2018; Frey, 2019; Acemoglu and Johnson, 2024). After a century of skill-biased technological change, concerns over deskilling have recently reignited, as skilled workers appear to be the ones most exposed to technological advances in the twenty-first century (Eloundou et al., 2024; Liu et al., 2025; Althoff and Reichardt, 2026).

Influential contemporaries across the political spectrum—from Smith to Marx—viewed the rise of the factory as fundamentally deskilling. Today, economists largely echo that interpretation. For example, the canonical account by Goldin and Katz (2008, p. 124) concludes that "the industrial revolution with the shift into various types of factories was, overall, deskilling", while Acemoglu (2002, p. 12) characterizes the factory as the most skill-replacing technology of the past two centuries. At the same time, a growing body of work shows that technological advances during industrialization often increased the demand for skills (for example, Caselli, 1999; Autor et al., 2020; Franck and Galor, 2022; Becker et al., 2026), while reviews of the literature conclude that there is no empirical support for the deskilling thesis (Brugger and Gehrke, 2018).[1]

A lack of consensus on the skill bias of technological change during industrialization partly reflects the scope of existing evidence, which often examines a single country, industry, or technology. Yet as Acemoglu (2002, p. 8) noted: "[i]n the absence of detailed econometric evidence, it is difficult to generalize from the historical examples and conclude that technical change was definitely skill-replacing during the nineteenth century." More than two decades later, the central empirical challenge remains: we lack data that permit a systematic econometric analysis of whether deskilling was a general feature in countries undergoing industrialization.

This paper provides a systematic examination of the deskilling thesis by leveraging recently digitized firm-level census data for more than half a million manufacturing firms in

[1]The lack of consensus is underscored by the fact that even leading authorities have advanced opposing conclusions over time: while Goldin and Katz (2008, p. 124) concluded that "the switch to the factory most likely *decreased* the demand for skilled relative to unskilled labor in manufacturing", Katz (2025, p. 2) more recently argued that "[t]he shift from the artisanal shop to the factory and larger-scaled enterprises with water and steam power [...] increased the demand for more-educated workers" (also see Autor et al. (2020)).

nineteenth-century Europe and the United States. The data enable a systematic analysis of the relationship between firm size, technology use, and the composition of the workforce in Russia, Sweden, and the United States—three countries that differ considerably in terms of culture, industrialization, and labor-market institutions (see Online Appendix A)—allowing me to examine whether deskilling was a general feature of industrialization.

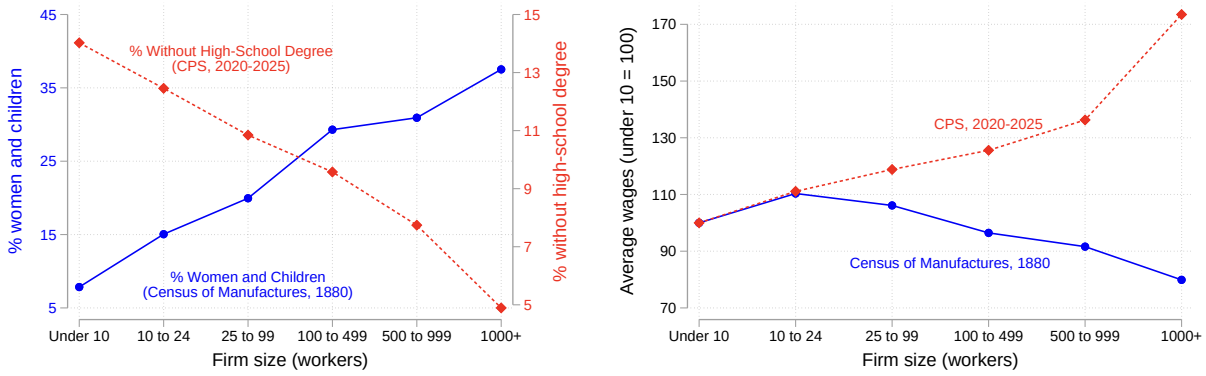
To examine whether the rise of the factory involved a deskilling of the industrial workforce, I focus on the employment of women and children—the only consistently available proxy for skill in historical census data. On average, women and children had lower levels of skills than adult male workers, earned lower wages, and disproportionately occupied less-skilled roles on the factory floors (Goldin and Sokoloff, 1984; Goldin, 1990; Burnette, 2008; Burnette and Stanfors, 2020; Humphries and Weisdorf, 2015; Delabastita et al., 2025). Moreover, women and children constitute a relevant measure of unskilled workers because (i) they constituted a large share—about a quarter to a third among the firms in the sample—of the industrial workforce; and (ii) because contemporary concerns about deskilling focused precisely on the substitution of women and children for skilled adult male workers in the factory (Ure, 1835; Gaskell, 1833; Marx, 1976).[2]

I show that the rise of the factory was associated with a substantial deskilling of the workforce by comparing firms active within the same detailed industry and location, which absorbs a wide range of factors that may shape firms' employment decisions that vary either across locations or industries. In all countries and within virtually all industries, I find a greater share of unskilled workers in larger firms, which is corroborated in a battery of additional checks. Figure 1 contrasts these historical patterns with the modern context, by showing that the skill intensity across the firm size distribution has reversed over the past century.

To go beyond a purely descriptive account, I use two complementary approaches. First, I construct an instrument for firm size using a leave-one-out logic based on average size of firms in the same granular industry located in other regions, which uses the fact that some goods are efficiently produced in larger establishments than others. Second, I use probabilistic linkage techniques to track Swedish and U.S. firms across censuses. Both instrumenting for firm size and exploiting changes in size within firms show that larger firms increased their employment of women and children and reduced the average wages paid to workers.

Why was the rise of the large factory associated with deskilling? I examine two broad explanations. First, a traditional explanation going back to contemporaries such as Gaskell

[2]However, it is an open question whether the employment of women and children correlates with other measures of worker skills. Using matched worker-firm data for Swedish firms in the early twentieth century, I show that the share of women and children in a firm is associated with a lower share of educated workers and a larger share of unskilled jobs (see Online Appendix F).



(A) Unskilled Workers (B) Average Wages

Figure 1: Firm Size and Skill Intensity in the Nineteenth and Twenty-First Centuries

Notes: This figure shows that larger manufacturing firms in the nineteenth century employed relatively more unskilled workers (Panel A) and paid lower average wages (Panel B) compared to smaller firms, whereas larger manufacturing firms today employ relatively more skilled workers and pay substantially higher wages. The historical data are drawn from the 1880 Census of Manufactures restricted to firms operating full-time, year-round, with at least one worker and reported wages. The modern data come from the IPUMS 2020–2025 CPS ASEC samples (Flood et al., 2025), restricted to full-time wage and salary workers in manufacturing aged 16–64 with one employer in the previous calendar year. For these respondents, I use reported total pre-tax wage and salary income and an indicator for lacking a high-school degree, and calculate averages across firm-size categories using the supplied person weights. Both samples are trimmed by excluding the top and bottom wage percentiles.

(1833), Ure (1835), and Marx (1976) is that the main driver behind deskilling during the rise of the factory was the adoption of steam power that facilitated mechanization (Landes, 1969). Second, an alternative explanation instead highlights organizational changes—that occurred both in mechanized and non-mechanized firms—that enabled a greater division of labor and task simplification, a more disciplined work regime, and managerial control, which facilitated the employment of unskilled workers such as women and children (Pollard, 1963, 1965; Braverman, 1974; Marglin, 1974; Goldin and Sokoloff, 1982; Atack et al., 2024).

I first provide suggestive evidence that larger firms had a greater division of labor, more intensive work regimes, and more developed formal supervision. Then, I systematically document that American, Swedish, and Russian firms that did *not* rely on inanimate power exhibit a similarly strong link between firm size and unskilled labor, which I corroborate by examining the hand-powered brickmaking industry where larger brickworks employed greater shares of women and children, which historical sources mainly attribute to organizational differences. In contrast to traditional explanations, I show that firms that relied on steam power employed substantially *fewer* women and children and paid higher average wages, both consistent with a greater skill intensity. Together, these findings suggest that organizational

changes may have been an important driver of deskilling.

I contribute systematic evidence that deskilling accompanied the rise of the factory. As discussed in more detail in the next section, existing studies have often focused on individual countries, industries, or technologies (Goldin and Sokoloff, 1982; Katz and Margo, 2014; Cockriel, 2024; Vipond, 2025; Allen, 2018; Atack et al., 2024; Acemoglu and Johnson, 2024; Schneider, 2026), leaving open whether deskilling was a more general feature of industrialization. I show deskilling was prevalent in three very different industrializing countries and within a wide range of industries, which provides a stronger empirical foundation for the canonical view that industrialization involved deskilling (Braverman, 1974; Acemoglu, 2002; Goldin and Katz, 2008).

However, my findings contrast with the traditional view that the main driver of deskilling was technological change by showing that the transition to steam was associated with a greater demand for skill, consistent with a growing body of work (Caselli, 1999; Atack et al., 2004; Autor et al., 2020; De Pleijt et al., 2020; Franck and Galor, 2022; Becker et al., 2026; Berger, 2026). Instead, deskilling appears to mainly have been driven by organizational changes consistent with evidence of deskilling before steam became widespread and in industries with limited mechanization (Marglin, 1974; Goldin and Sokoloff, 1982; Sokoloff, 1984; Katz and Margo, 2014), as well as Atack et al. (2024) showing that organizational changes were a key driver of deskilling.

An implication is that when discussing the impacts of the factory on the demand for skills, one should make a distinction between the factory as an organizational form (reducing the demand for skill) and the technologies adopted within it (raising the demand for skill), which could potentially reconcile disagreements over how the rise of the factory shaped the demand for skills. A second implication is that past technological change may not have been so different from the technologies of the twentieth and twenty-first centuries—electricity, the internet, or industrial robots—which reduced the relative demand for unskilled workers (Goldin and Katz, 1998; Akerman et al., 2015; Acemoglu and Restrepo, 2020; Restrepo, 2024).

2 Context: Deskilling and the Rise of the Factory

Industrial production was historically dominated by skilled artisans who carried out the entire production process relying on hand tools. However, by the early twentieth century, the factory—combining inanimately-powered machinery with a large workforce—had largely displaced artisanal production.

Classical economists including Smith and Ricardo believed the factory entailed a per-

vasive deskilling of the industrial workforce, by decomposing production into simpler tasks and substituting unskilled workers and machinery for craft knowledge. In particular, the concerns and moral outrage were directed at the adoption of powered machinery and the rising employment of women and children that displaced adult male workers (Humphries, 2010; Tuttle, 2021), which was manifested in worker resistance to new technologies (Nuvolari, 2002; Frey, 2019; Caprettini and Voth, 2020). Notably, according to contemporary observers this was not an incidental consequence of the factory system but one of its defining features:

> It is, in fact, the constant aim and tendency of every improvement in machinery to supersede human labour altogether, or to diminish its cost, by substituting the industry of women and children for that of men; or that of ordinary labourers, for trained artisans. (Ure, 1835, p. 23)

However, the subsequent empirical literature is inconclusive regarding whether the rise of the factory generally led to deskilling. An influential strand of the empirical literature supports the still canonical view of the classical economists (Acemoglu, 2002; Goldin and Katz, 2008). In early U.S. manufacturing, Goldin and Sokoloff (1982) shows that women and children became increasingly important and that larger establishments relied more heavily on unskilled labor (also see Katz and Margo (2014)). At the same time, other evidence points to a more direct substitution of capital for skill (James and Skinner, 1985) and that technological breakthroughs in specific industries reduced the earnings and employment of incumbent workers (Cockriel, 2024; Vipond, 2025; Allen, 2018; Acemoglu and Johnson, 2024; Schneider, 2026).

By contrast, a recent body of work instead emphasizes that the rise of the mechanized factory often raised the demand for skill (Caselli, 1999; Bessen, 2011; Autor et al., 2020; Katz, 2025). Evidence from the diffusion of the steam-powered factory points to greater human capital accumulation and demand for skills in Britain, France, and Germany (De Pleijt et al., 2020; Franck and Galor, 2022; Becker et al., 2026), while other studies show that mechanization reduced reliance on child labor (Brown et al., 1992; Ridolfi et al., 2023; Berger, 2026). Atack et al. (2004) show that wages were higher in more capital-intensive and steam-powered U.S. firms, indicating a greater skill intensity, while Autor et al. (2020) interpret the evolution of relative wages as reflecting a rising relative demand for educated labor, echoing evidence that there was no clear deskilling in the aggregate labor market (Katz and Margo, 2014; Heikkuri, 2026). More broadly, a review of the empirical evidence by Brugger and Gehrke (2018, p. 686) concludes:

> [W]e found no evidence that technical change was on average predominantly deskilling in this period. Hence, the often-viewed opinion that nineteenth-century

technical change had a strong overall bias against skilled labour may be due to a generalisation of catchy stories, but lacks empirical support.

Whether deskilling was a general feature of industrialization thus remains an open question, not least because it is hard to generalize from existing studies that focus on individual countries, industries, or technologies.

3 Data

I construct a firm-level dataset that allows for a systematic analysis of a firm's scale, technology use, and workforce composition by drawing on recently digitized manufacturing census data for the United States, Sweden, and Russia. For simplicity, although the censuses were collected at the establishment level, I refer to these units as "firms" throughout the paper, since multi-unit firms were rare in the nineteenth century.

United States I use the complete surviving firm-level manuscripts of the 1870 and 1880 Census of Manufactures from Hornbeck et al. (2024). Enumerators were instructed to record all manufacturing firms with at least $500 in annual sales, which implies that only very small firms were excluded. The manuscripts report the average number of adult men (above 16), women (above 15), and children/youth employed (Atack and Bateman, 1999), which I use to construct the share of women and children in each firm. I also observe each firm's power source and horsepower, capital and output, total wage payments, operating time, and county/state and industry.[3] To link U.S. firms between the 1870 and 1880 censuses, I use a probabilistic record linkage algorithm that links firms with similar firm/owner names that are active in the same county and industry, as described in more detail in Online Appendix H.

Sweden I use the recently digitized Swedish manufacturing census that collected annual information on all firms that were active within manufacturing proper (Almås et al., 2026). Each firm reports employment by sex (men and women) and age (above and below 18), which I use to calculate the share of women and children in the workforce. Firms also reported their industry, ownership, output, and use of power technologies (steam, water, and animal) and total horsepower. In the panel regressions, I rely on a balanced sample of linked firms that are linked over time using probabilistic linkage algorithms and manual review based on

[3] I define annual earnings per worker as the reported annual wage bill divided by reported average employment following the adjustments in Atack et al. (2002) and Atack et al. (2004), while excluding firms with missing or non-positive wage bills, employment, or required operating-time inputs.

firm/owner names, geographical location, and industry, as described in Almås et al. (2026). Throughout, I restrict the sample to 1864–1895, starting with the major institutional reforms of the Freedom to Trade Act of 1864 and ending in 1895 before the manufacturing census underwent substantial changes.

Russia I use the 1894 manufacturing census compiled by the Imperial Ministry of Finance that provides data on factories in the Russian Empire (Gregg, 2020). The census aimed to cover factories, rather than small workshops: information was to be collected for firms with at least 15 employees, a steam boiler/engine, or other factory devices. While the 1894 census therefore has better coverage of larger firms, it also includes smaller firms that rely on steam and many smaller firms without reported machinery (Gregg and Matiashvili, 2022). The census reports data on firms' employment of women and children (under 18), which I use to construct the share of women and children in each firm. The census also contains information on location (city or *uezd*), industry, output, the number of working days per year, as well as power technologies and horsepower.

Sample Definitions After merging the census data, the dataset contains information on more than half a million industrial firms. I restrict the sample to firms with at least two workers (to exclude artisans working on their own) and no more than 1,000 workers (to exclude firms that likely jointly reported information for several different establishments) and harmonize the granular industry classifications into eight broad industry groups and twenty detailed industry groups. Online Appendix Table B1 provides summary statistics and industry classifications for the approximately 344,000 firms included in the main sample.

4 Analysis

4.1 Empirical Strategy

I first provide descriptive OLS regressions that compare the employment of women and children in industrial firms across the firm size distribution:

$$U_{it} = \alpha + \lambda_t + \sum_{k=1}^{K} \theta_k \mathbb{1}\{\ln(\text{Size}_{it}) \in B_k\} + \varepsilon_{it}. \tag{1}$$

where U_{it} is the percentage share of workers who are women or children, λ_t is a year fixed effect, and Size_{it} denotes the number of workers. I create bins of log firm size in intervals of 0.25 among firms with at least five workers and group firms with 100 or more workers in the top bin; the estimates of θ_k capture how the employment share of women and children

varies in larger firms relative to the omitted category of firms with fewer than five workers, but could reflect a number of omitted factors that may be correlated with firm size.

I therefore use three complementary empirical approaches. First, I estimate pooled OLS regressions of the form:

$$U_{it} = \delta_{trj} + \beta \ln(\text{Size}_{it}) + \varepsilon_{it}, \tag{2}$$

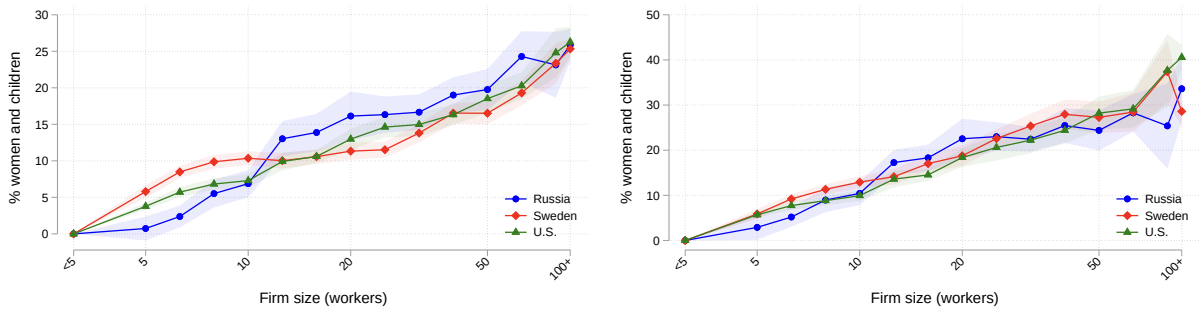
where U_{it} is the percentage share of workers who are women or children, and $\ln(\text{Size}_{it})$ is the natural log of the number of workers in firm i in year t. A key concern is that the association between firm size and the employment share of women and children partly reflects underlying differences across regions (for example, child labor laws, poverty rates, or urbanity) or industries (for example, due to social norms shaping women's employment opportunities). The regressions therefore include region-by-detailed industry-by-year fixed effects (δ_{trj}), where r denotes region—city or *uezd* in Russia, district (*fögderi*) in Sweden, and county in the United States—and j denotes the consistently defined 20 detailed industry groups. The identifying variation thus comes from differences across firms in the same detailed industry, region, and year, which absorbs a wide variety of potential omitted factors that vary across regions and industries.

A remaining empirical challenge is that firm size is an endogenous choice. Even among firms operating in the same region, industry, and year, unobserved productivity or managerial capacity may jointly shape an establishment's scale and workforce composition. Moreover, access to inexpensive female and child labor may itself allow firms to expand, while measurement error in reported employment would attenuate the OLS estimates.

To address these concerns, the second empirical approach instruments firm size using the leave-one-out average size of firms in the same granular industry in other regions, shifting the identifying variation toward differences in an industry's efficient scale of production rather than firm-specific labor demand.[4] The exclusion restriction may nevertheless fail if granular industries characterized by larger firms also differ in technologies or social norms that directly affect their reliance on women and children. I address this concern by controlling for power use and residual female and child employment in the same granular industry elsewhere, although these controls cannot rule out all unobserved industry-level differences.

Third, I leverage the longitudinal nature of the Swedish and U.S. data to examine how the employment of women and children changes as firms grow and adopt new technologies. I estimate firm-level panel OLS regressions:

[4]The granular industries are based on the most detailed industrial classifications in each respective census and include 469, 170, and 303 different industries in Russia, Sweden, and the United States, respectively.



(A) All Firms (B) Non-Powered Firms

Figure 2: Firm Size and Unskilled Labor

Notes: This figure displays differences in the percentage of workers who are women or children across bins of log firm size, relative to firms with fewer than five workers. Panel A includes all firms; Panel B restricts the sample to firms that use neither steam nor water power. Among firms with at least five workers, bins are 0.25-wide intervals of log firm size; firms with 100 or more workers are grouped in the top bin. The x-axis reports worker counts corresponding to selected log-size bins. The Sweden and U.S. specifications include year fixed effects, while the Russia specification is a single cross section. Shaded areas denote 95% confidence intervals based on standard errors clustered at the city/*uezd* level in Russia, district-by-year in Sweden, and county-by-year in the United States.

$$U_{it} = \alpha_i + \lambda_t + \beta \ln(\text{Size}_{it}) + \gamma_1 \text{Steam}_{it} + \gamma_2 \text{Water}_{it} + \varepsilon_{it}, \tag{3}$$

where α_i and λ_t denote firm and year fixed effects, U_{it} is the percentage share of women and children in firm i in year t, and $\ln(\text{Size}_{it})$ is the natural log of the number of workers. In the Swedish panel, *Steam* and *Water* switch to one when adoption of the respective technology likely began, whereas in the U.S. panel they capture reported power use in each census year. Additional specifications also include a wider set of region and industry-by-year fixed effects and flexibly control for baseline firm characteristics—ln firm size, an indicator for corporate ownership, and the percentage share of women and children—that may have shaped a firm's decision to expand and adopt new technologies (Gregg, 2020; Berger and Ostermeyer, 2025).

4.2 Main Results

4.2.1 OLS Estimates

Figure 2, Panel A, displays estimates of θ_k in Equation (1) that capture differences in the percentage share of workers who were women or children across bins of log firm size. In all three countries, women and children constituted a greater share of employment in larger firms.[5] In the top bin—firms with 100 or more workers—the share of women and children was

[5]Online Appendix Figure B1 shows that the pattern is similar when examining raw shares across the firm size distribution in all three countries.

about 25 to 26 percentage points higher than among firms with fewer than five workers.[6] However, these estimates are merely descriptive and I therefore next show that a similar association persists when comparing firms operating in the same detailed industry, region, and year.

Table 1, Panel A, presents estimates of Equation (2). A strong positive link between firm size and the employment share of women and children persists when comparing firms active in the same detailed industry and region in columns 1, 3, and 6. The estimated OLS slopes are similar across countries and imply that a doubling in firm size (say from 10 to 20 workers) is associated with about a 2.1 to 2.3 percentage point increase in the employment share of women and children.

I provide a battery of robustness checks in Online Appendix C.1 showing that the association between firm size and the share of women and children appears in most industries, when using a variety of measures of firm size, when considering the employment of women and children separately, and when examining firms that differ in terms of ownership, geography, or seasonality. Online Appendix F further uses matched worker-firm data to show that larger firms employed relatively more unskilled workers also when using other other measures of worker skills—including education and unskilled occupations—and that these firm-level skill measures are highly correlated with the share of women and children in the workforce.

4.2.2 IV Estimates

Table 1, Panel A, Columns 2, 4, and 7 report the 2SLS estimates for Russia, Sweden, and the United States, respectively, and confirm that the share of women and children sharply increased with firm size, which is evident across industries (Online Appendix Figure D2).[7] Online Appendix Figure D1 and Table D1 document a strong reduced-form association between the instrument (the average firm size among firms in the same granular industry located in other regions) and the share of women and children. Consistently, the 2SLS estimates in Table 1 are larger than the corresponding OLS estimates, consistent with measurement error or omitted variables biasing OLS downward as discussed above.

A key concern with the instrument is that differences in firm size may be correlated

[6] To gauge the aggregate relevance of the finding that large firms employed relatively more women and children, Online Appendix Figure B3 shows that large firms accounted for the largest shares of women's and children's employment, suggesting that the shift from small artisan shops to large factories was central to the rise in the employment of women and children.

[7] A strong first stage association exists and the inference is robust to accounting for weak instruments: the first-stage F-statistics reported at the bottom of Table D1 are large and Online Appendix Table D2 shows that the estimates remain statistically significant at the 5% level using Anderson–Rubin inference in all three countries, though the Swedish estimate is less precise.

Table 1: Firm Size, Technology Use, and Unskilled Labor

	Outcome: % women and children							
	Russia (1894)		Sweden (1864–1895)			U.S. (1870–1880)		
	OLS	2SLS	OLS	2SLS	Panel	OLS	2SLS	Panel
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. All Firms								
Firm size (ln)	3.218***	7.619***	2.995***	5.124**	5.972***	3.287***	7.046***	4.288***
	(0.397)	(1.262)	(0.837)	(2.350)	(0.694)	(0.181)	(0.600)	(0.366)
Region × industry × year FE	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Firm FE	No	No	No	No	Yes	No	No	Yes
Year FE	No	No	No	No	Yes	No	No	Yes
Kleibergen–Paap F-statistic	—	271.19	—	103.54	—	—	2377.04	—
Mean outcome	15.73	15.52	22.90	21.20	25.34	9.99	9.98	14.16
Observations	14079	13883	58542	55746	17787	246960	246925	15676
Panel B. Non-powered firms								
Firm size (ln)	5.181***	19.174***	3.162***	0.539	6.798***	4.453***	15.295***	4.938***
	(0.944)	(2.005)	(0.615)	(2.297)	(0.837)	(0.344)	(1.648)	(0.446)
Region × industry × year FE	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Firm FE	No	No	No	No	Yes	No	No	Yes
Year FE	No	No	No	No	Yes	No	No	Yes
Kleibergen–Paap F-statistic	—	104.82	—	17.29	—	—	3851.88	—
Mean outcome	19.70	19.46	21.77	20.83	25.63	11.92	11.92	13.98
Observations	6754	6593	29213	28392	12267	145274	145238	13300
Panel C. All Firms: Technology Use								
Firm size (ln)	3.673***	9.222***	3.785***	5.880**	6.180***	3.812***	10.906***	4.549***
	(0.401)	(1.380)	(0.724)	(2.617)	(0.691)	(0.218)	(0.959)	(0.384)
Steam power (=1)	-2.860***	-7.814***	-4.225***	-6.973***	-2.392**	-3.465***	-11.063***	-2.794***
	(1.027)	(0.912)	(0.928)	(2.548)	(0.960)	(0.355)	(1.229)	(0.968)
Water power (=1)	-3.528***	-5.691***	-1.404	-3.143	0.962	-2.466***	-5.589***	-4.417**
	(0.920)	(0.913)	(1.303)	(2.071)	(1.190)	(0.245)	(0.510)	(2.105)
Region × industry × year FE	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Firm FE	No	No	No	No	Yes	No	No	Yes
Year FE	No	No	No	No	Yes	No	No	Yes
Kleibergen–Paap F-statistic	—	170.31	—	113.40	—	—	1655.16	—
Observations	14079	13883	58542	55746	17787	246960	246925	15676

Notes: Firm-level OLS, 2SLS, and panel OLS regressions of the percentage of workers who are women or children. Panel A reports the baseline estimates. Panel B restricts the sample to firms that use neither steam nor water power; panel firms remain non-powered in every observed year. Panel C includes steam- and water-power indicators. In the Swedish panel specification (column 5), the indicators switch to one when adoption of the respective technology likely began, whereas in the U.S. panel specification (column 8) they capture reported power use in each census year. Both panel samples exclude firms reporting either power source at entry. Columns 2, 4, and 7 instrument firm size using average ln firm size in the same granular industry in other regions; Panel B constructs the instrument among non-powered firms. Region is city/*uezd*, district (*fögderi*), and county in Russia, Sweden, and the United States, respectively. Industry is the harmonized set of 20 detailed groups. Standard errors are clustered at the region level in columns 1–4 and 6–7 and at the firm level in columns 5 and 8. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

with, for example, the degree of mechanization or the stigma relating to women and children working in particular industries. Online Appendix Table D1 reports estimates when controlling for the use of steam and water power, defined analogously to the instrument, and

the residual employment shares of women and children that proxy for potential stigma in their employment across industries. There remains a large positive link between firm size and the employment of women and children, though the results for Sweden are imprecisely estimated. To examine robustness to potential violations of the exclusion restriction, I follow Caprettini and Voth (2023) and apply the method of Conley et al. (2012) to show that the direct effect of the instrument has to be substantial to turn the IV estimates insignificant.[8]

4.2.3 Panel Estimates

Table 1, Panel A, Columns 5 and 8 use the linked Swedish and U.S. samples and present estimates of Equation (3) showing that the employment of women and children increased as firms grew larger. A doubling in firm size is associated with an increase of about 4.1 and 3.0 percentage points in the employment share of women and children in Sweden and the U.S., respectively.[9] Similar to the IV estimates, the within-firm association between firm size and the share of women and children is larger compared to the baseline OLS estimates, which again is consistent with a downward bias in the OLS estimates discussed above.

A natural concern is that the employment of women and children may shape future firm growth, yet Online Appendix Table E1 shows that estimates are similar when controlling for a wide range of baseline firm characteristics including the share of women and children. Another concern given that firms are probabilistically linked is that linkage quality may shape the estimated association. However, Online Appendix Figure E2 shows that the estimated association between firm size and the employment of women and children remains similar in magnitude when restricting the U.S. sample to higher-quality links.

Alternative Measures of Deskilling: Wages As shown in Figure 1, Panel B, there exists a negative cross-sectional association between firm size and average wages across U.S. firms in 1880 (also see (Atack et al., 2004)), which contrasts modern patterns and indicates a lower skill intensity in large firms historically. Table 2 presents corresponding panel estimates: the elasticity between average wages and firm size in column 1 is -0.119, indicating that a 10 percent increase in firm size is associated with about 1.2 percent lower average wages. The elasticity remains similar when adding county-by-industry-by-year fixed effects

[8] In the baseline specification, the direct effect of the instrument would have to account for about 70% of the reduced-form relationship in Russia and 85% in the United States before the 95% union confidence set includes zero; these thresholds remain similar when including the full IV controls (Online Appendix Figure D3). However, the corresponding threshold is about 10% in the baseline specification and 15% with the full controls in Sweden, indicating that the Swedish estimates are less robust to moderate violations of the exclusion restriction.

[9] Again, the positive link is evident in most industries (Online Appendix Figure E1).

TABLE 2: FIRM SIZE, TECHNOLOGY USE, AND WAGES IN THE UNITED STATES

	Outcome: ln FTE annual wages per worker					
	All firms		Non-powered firms		All firms	
	(1)	(2)	(3)	(4)	(5)	(6)
Firm size (ln)	-0.119***	-0.111***	-0.124***	-0.095***	-0.135***	-0.128***
	(0.008)	(0.009)	(0.012)	(0.013)	(0.009)	(0.010)
Steam power (=1)					0.138***	0.158***
					(0.019)	(0.022)
Water power (=1)					0.032	0.026
					(0.034)	(0.039)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County × industry × year FE	No	Yes	No	Yes	No	Yes
Mean outcome	5.95	5.98	5.95	5.98	5.95	5.98
Observations	25954	21776	12568	9988	25954	21776

Notes: Firm-level panel OLS regressions for linked U.S. firms observed in 1870 and 1880. The dependent variable is the log of full-time-equivalent annual wages per worker. Columns 1–2 use all linked firms, columns 3–4 restrict the sample to firms that used neither steam nor water power in either year, and columns 5–6 use all linked firms and control for steam and water power, which capture within-firm changes. The county-by-industry-by-year fixed effects compare firms in the same county and harmonized 20-group industry within each census year. Standard errors clustered at the firm level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in column 2, when restricting the sample to firms operating full-time (accounting for seasonality) in both years (Online Appendix Table E2), or to higher-quality links (Online Appendix Table E3).

Together, these results show that firms that grew larger also paid substantially lower average wages further suggesting that the rise of the large factory was associated with deskilling. However, these estimates do not shed light on the underlying mechanisms.

4.3 Mechanisms: Organizational and Technological Changes

A positive association between firm size and the employment of women and children could reflect two broad mechanisms: organizational and technological changes. First, it is widely emphasized that a key driver of deskilling was the greater division of labor and factory discipline enabled by the rise of larger enterprises (Pollard, 1963, 1965; Braverman, 1974; Marglin, 1974; Goldin and Sokoloff, 1982; Clark, 1994; Humphries, 2003; Atack et al., 2024). Second, many influential contemporaries such as Gaskell (1833), Ure (1835), and Marx (1976) and later scholarship have argued that the adoption of steam power was the underlying key driver

of deskilling (Landes, 1969), which is underscored by the fact that the adoption of steam was spearheaded by larger firms (Atack et al., 2008; Berger and Ostermeyer, 2025). While technological and organizational changes in many cases were deeply intertwined (Gregg, 2020; Juhász et al., 2024; Berger and Ostermeyer, 2025), the two margins are conceptually distinct as evident by the fact that many firms underwent substantial organizational change without adopting new technologies.[10]

4.3.1 Organizational Changes

A key limitation in historical census data is the lack of direct measures of the internal organizational structure of firms. Using unique matched worker-firm data based on detailed surveys of early twentieth century Swedish printing firms, Online Appendix F documents suggestive evidence on organizational differences across the firm size distribution: the division of labor, work intensity, and development of managerial hierarchies were substantially greater among larger firms. However, these differences could be driven by the greater technology use within large enterprises.

To provide more systematic but indirect evidence that organizational factors shaped the employment of unskilled workers even in the absence of the adoption of new power technologies, I examine the share of women and children among firms that used neither steam nor water power. Figure 2, Panel B, shows that the firm-size gradient is similar in all three countries, which is evident within most broad industries (Online Appendix Figure C2). Table 1, Panel B, further shows that the positive size gradient persists among non-powered firms. The OLS estimates imply that a doubling in firm size is associated with a 2.2 to 3.6 percentage point increase in the share of women and children, while the 2SLS and panel estimates imply larger increases, though the Swedish 2SLS estimate is small and imprecise.

To make the role of organizational innovations more concrete, I zoom in on brickmaking in Online Appendix G—an industry producing a relatively homogeneous good with limited adoption of inanimate power. Yet there existed stark organizational differences between small and large non-mechanized brickyards: small brickyards and large urban brickworks used broadly similar methods of clay preparation, molding, and firing, relying on hand molds or simple presses, and comparable kiln technologies. However, large firms employed more unskilled labor—including women and children, often in family gangs—to perform tasks such

[10] At least three major organizational innovations reshaped firms that did not adopt inanimate power. First, the decomposition of skilled artisanal work into simple repetitive tasks that unskilled workers could perform (Marglin, 1974; Braverman, 1974; Goldin and Sokoloff, 1982; Sokoloff, 1984; Atack et al., 2024). Second, the concentration of formerly dispersed workers under one roof lowering the cost of monitoring and coordination (Pollard, 1965; Marglin, 1974), and the related imposition of factory discipline—fixed hours, attendance rules, and continuous supervision (Pollard, 1963; Clark, 1994). Third, the rise of managerial structures that coordinated workers within larger firms (Chandler, 1977; Engbom et al., 2025).

as gathering clay, hauling bricks, and assisting male molders with edging and spatting. As described in the Online Appendix, the expansion in scale among these hand-powered firms rested on a greater division of labor and more developed supervision.

Taken together, the fact that deskilling is similarly evident among firms that did not rely on new technologies is difficult to reconcile with the idea that technological change was the fundamental driver behind deskilling. Indeed, I next show that the use of steam power is *negatively* associated with the reliance on unskilled workers.

4.3.2 Technological Changes

Table 1, Panel C, compares industrial firms in Russia, Sweden, and the United States showing that the association between a firm's use of steam power and the share of women and children is large and negative. The estimated magnitudes are large in relative terms: U.S. firms relying on steam power employed about 3.5 percentage points fewer women and children in the OLS specification, which is sizable compared to the mean share of women and children of about 10 percent in the sample. Similarly, water power use is also negatively related to unskilled labor, but less precisely estimated in Sweden.

Columns 5 and 8 of Table 1 report difference-in-differences estimates showing that the adoption of steam power was associated with a decline in the share of women and children of about 2.1 and 2.8 percentage points in Sweden and the U.S., respectively, which remain relatively large effects compared to the sample means. Water-power use is also associated with large declines in the U.S., though the reductions are smaller and imprecisely estimated in the Swedish sample.[11] Similarly, Table 2, Columns 5–6, show that the adoption of steam power is associated with a 14 to 16 log point increase in average wages per worker among U.S. firms, which again is consistent with a greater skill intensity after a firm transitions to steam technology.

Together, these results suggest that while the rise of the large factory involved widespread deskilling, the main driver was not the adoption of new inanimate power technologies, which contrasts traditional accounts that ascribe deskilling primarily to the transition to inanimate power. Instead, it appears that deskilling can more plausibly be ascribed to broader organizational changes that took place both within mechanized and non-mechanized firms alike.

[11] While the U.S. sample contains only two periods, the Swedish data allow me to examine trends in the employment of women and children before the transition to steam power. Online Appendix Figure E3 presents standard event studies and using the estimator of de Chaisemartin and D'Haultfœuille (2026) showing that there are no systematic pre-trends prior to the transition to steam, while there is a sharp decline after steam is installed.

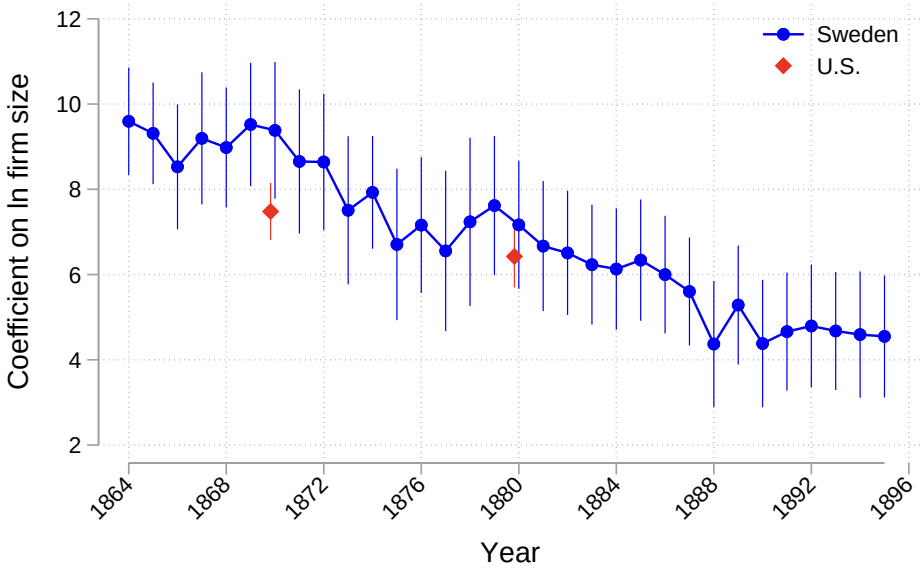


FIGURE 3: FIRM SIZE AND UNSKILLED LABOR: GRADIENTS OVER TIME

Notes: This figure displays year-specific coefficients from firm-level regressions of the percentage of workers who are women or children on ln firm size for Swedish manufacturing firms observed between 1864 and 1895, with comparison estimates for U.S. manufacturing firms in 1870 and 1880. The regressions control for steam and water power. All samples are restricted to firms with 2–1,000 workers. Vertical lines denote 95% confidence intervals based on standard errors clustered by registration district in Sweden and county in the United States.

5 Concluding Questions: Why Did Deskilling End?

I use data on hundreds of thousands of industrial firms in Russia, Sweden, and the U.S. to show that larger firms employed substantially more unskilled workers across countries and industries, supporting the canonical deskilling view of Acemoglu (2002) and Goldin and Katz (2008). The findings raise the question: when did the positive association between firm size and unskilled labor in the nineteenth century reverse to the modern negative association shown in Figure 1, where large firms rely more intensively on skilled labor?

Figure 3 presents estimates from regressions of unskilled labor on firm size separately by year, which show that the firm-size gradient in unskilled labor weakened over time, falling by about 53 percent in Sweden between 1864 and 1895 and by about 14 percent in the United States between 1870 and 1880. While suggestive, these patterns are consistent with large firms becoming relatively more skill-intensive over the latter half of the nineteenth century and a reversal taking place sometime in the early twentieth century.

A reversal in the early twentieth century aligns with the view that attributes the shift to skill-biased technological change to electrification, which constituted a break with prior

deskilling technologies such as steam (Goldin and Katz, 1998). Yet evidence that the adoption of steam reduced the demand for unskilled labor already in the nineteenth century suggests that the shift from deskilling to skill-biased technological change may be traced to the earlier shift from hand to machine power. If technology always raised the demand for skills, it becomes less straightforward to interpret the reversal of skill intensity in Figure 1 simply as a story about new technologies. Instead, it could partly have reflected organizational changes associated with the rise of the managerial firm (Chandler, 1977). In that case, just like the onset of deskilling in the nineteenth century may partly have been driven by organizational changes, its undoing in the twentieth century may also have been driven by similar organizational forces.

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Online Appendix

Deskilling: Firm Evidence from Europe and the United States

A Additional Context: Russia, Sweden, and the U.S. **A2**

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A Additional Context: Russia, Sweden, and the U.S.

I focus on Russia, Sweden, and the United States partly because of the availability of comparable manufacturing census data, but also because they provide substantial cultural, economic, and institutional variation that is useful to examine whether deskilling was a general feature of industrialization across different historical contexts.

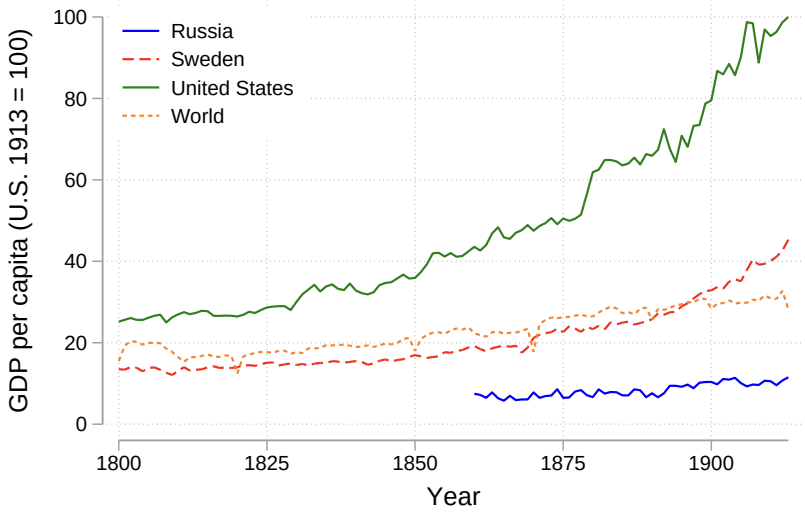
Online Appendix Figure A1 displays GDP per capita and industrial development in the three countries over the nineteenth century until the outbreak of World War I. By the late nineteenth century, the United States was emerging as the world's leading industrial economy underpinned by rapid integration of a vast internal market, the expansion of resource-intensive manufacturing, and urbanization (Wright, 1990; Donaldson and Hornbeck, 2016; Hornbeck and Rotemberg, 2024). In 1900, GDP per capita was more than twice as high in the United States as in Sweden and almost eight times as high as in Russia. U.S. industrial output per capita in 1913 was about twice the Swedish level and more than six times the Russian level, while U.S. urbanization rates were more than twice as high (see Table A1).

While initially a poor agricultural economy, Sweden experienced a rapid industrial take-off in the 1870s initially driven by an industrial expansion based around natural resources but increasingly revolving around advanced high-tech manufacturing toward the end of the century (Heckscher, 1954; Ljungberg and Schön, 2013; Schön, 2012). While it trailed far behind the U.S. in terms of GDP per capita, Swedish living standards as captured by heights and life expectancy surpassed the U.S. by the late nineteenth century (see Table A1). This take-off has partly been linked to Sweden's position as Europe's "impoverished sophisticate" (Sandberg, 1979), which is reflected in comparatively high levels of human capital both in terms of average years of education and numeracy considering its relatively low levels of GDP per capita (see Table A1). By contrast, Russia remained predominantly agrarian even though factory production expanded, which recent work attributes to the legacy of serfdom and limited human capital investments as key factors in explaining the limited industrial expansion and catch-up (Gregg, 2023; Markevich and Zhuravskaya, 2018; Zhuravskaya et al., 2024).

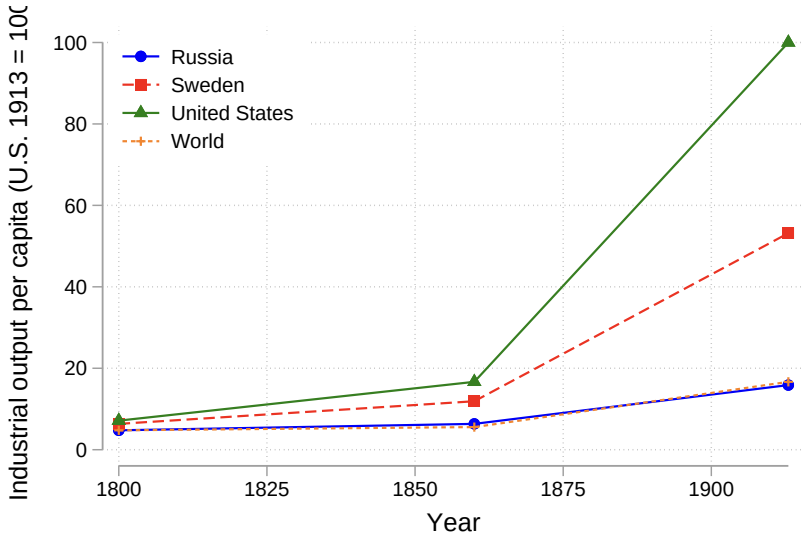
The different economic and industrial trajectories of Russia, Sweden, and the U.S. are also reflected in more fundamental drivers evident in Table A1, which displays a set of measures of political institutions and proxies for women's empowerment. Russia measures poorly in terms of institutional quality both compared to Sweden and the United States. Similarly, women's civil liberties and political empowerment lagged far behind in Russia, while Sweden exhibited greater levels of women's empowerment compared to the United States. The three countries also differed in their legislation of child labor. U.S. states began

to introduce restrictions on child labor in the latter half of the nineteenth century (Moehling, 1999), while Sweden and Russia introduced restrictions in the early 1880s (Gorshkov, 2009; Berger, 2026a). However, I account for state and national legislation through fixed effects in the analysis, and existing evidence suggests that child labor laws were largely ineffective in shaping the employment of children (Moehling, 1999; Berger, 2026b).

Together, the descriptive account above suggests that the firms I study are active in three countries that differ considerably in economic development, human capital, industrialization, institutions, and women's empowerment. The fact that the main result—the positive link between firm size and the employment of women and children—is so similar in these three countries strongly bolsters the interpretation that deskilling was a general feature of industrialization.



(A) GDP per Capita



(B) Industrialization

Figure A1: Growth and Industrialization in Russia, Sweden, and the United States

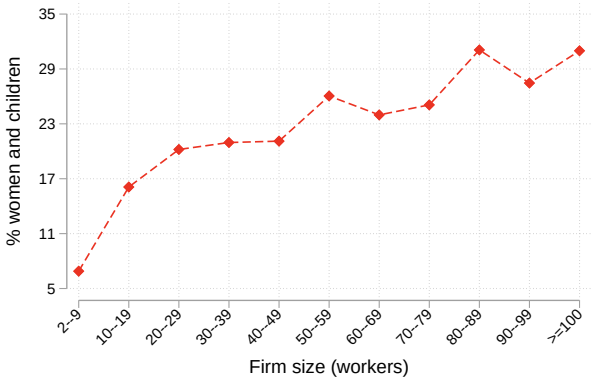
Notes: This figure displays GDP per capita (Panel A) and industrial output per capita (Panel B) for Russia, Sweden, and the United States, with a world reference series in each panel. GDP per capita data are from Bolt and van Zanden (2025); industrial output per capita data are from Bairoch (1982).

TABLE A1: DEVELOPMENT, POLITICAL INSTITUTIONS, AND CIVIL LIBERTIES

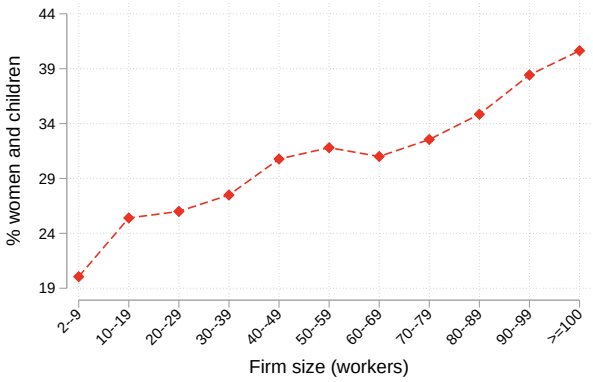
	Russia	Sweden	United States
Economic and human development			
GDP per capita, 1900	1,049	3,320	8,038
Industrial output per capita, 1913	15.9	53.2	100.0
Urbanization rate, 1880	10.6	12.5	25.0
Height, 1880	166.6	171.2	169.5
Life expectancy, 1880	31.7	47.7	39.4
Human capital			
Average years of education, 1880	1.00	4.61	6.02
Numeracy, 1880	94.7	100.0	95.4
Political institutions and civil liberties			
Electoral democracy, 1880	0.032	0.313	0.333
Rule of law, 1880	0.411	0.974	0.886
Political corruption, 1880	0.439	0.017	0.141
Freedom of expression, 1880	0.167	0.797	0.762
Freedom of association, 1880	0.077	0.840	0.862
Women's empowerment			
Women's political empowerment, 1880/1900	0.219	0.526	0.303
Women's civil liberties, 1880	0.163	0.747	0.435
Women's civil society participation, 1880	0.304	0.491	0.362

Notes: This table reports development, human-capital, institutional, and civil-liberties measures for Russia, Sweden, and the United States. GDP per capita is from the Maddison Project Database 2023 (Bolt and van Zanden, 2025) and is measured in 2011 dollars. Industrial output per capita is from Bairoch (1982) and is indexed so that the United States in 1913 equals 100. Urbanization is from Bairoch and Goertz (1986), Table 3, and is measured as the percentage of the total population living in cities of 5,000 or more inhabitants. Height, average years of education, and numeracy are from Clio Infra (Baten and Blum, 2015; van Leeuwen and van Leeuwen-Li, 2015; Baten, 2015). Clio Infra rows use 1880 when available, then 1900, and otherwise the nearest observation in 1870–1910. Height is male-height equivalent in centimeters, average years of education is for the population age 15 and above, and numeracy is the ABCC estimate in percent. Life expectancy is from the V-Dem Country-Year Dataset v16 (Coppedge et al., 2026) and is measured in years at birth. The political-institution and civil-liberties rows are also from V-Dem; women's political empowerment uses 1880 for Russia and 1900 for Sweden and the United States because the 1880 observations are missing. The democracy, rule-of-law, corruption, expression, association, and gender rows are 0–1 V-Dem indices. Electoral democracy summarizes suffrage, clean elections, elected officials, association, and expression. Rule of law captures transparent and predictable law, impartial administration, judicial constraints, and access to justice. The gender rows measure women's political empowerment, civil liberties, and civil-society participation.

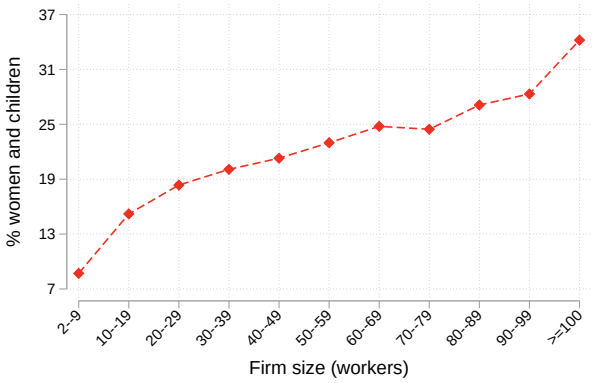
B Additional Descriptive Results



(A) Russia



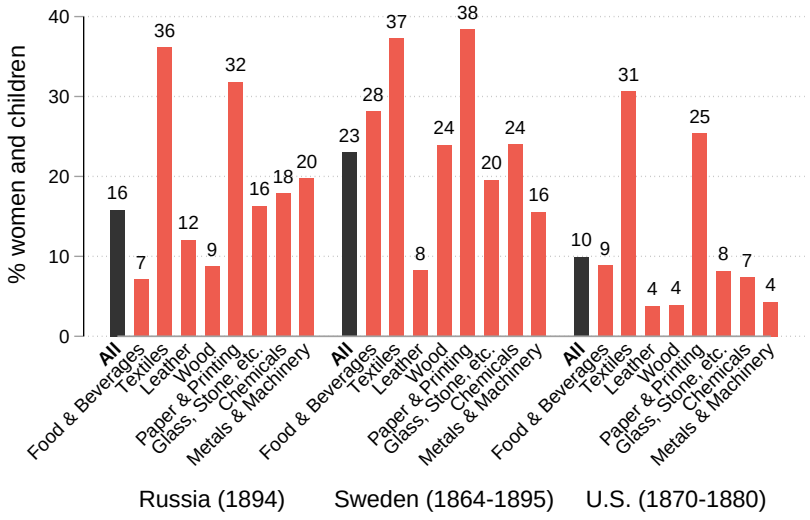
(B) Sweden



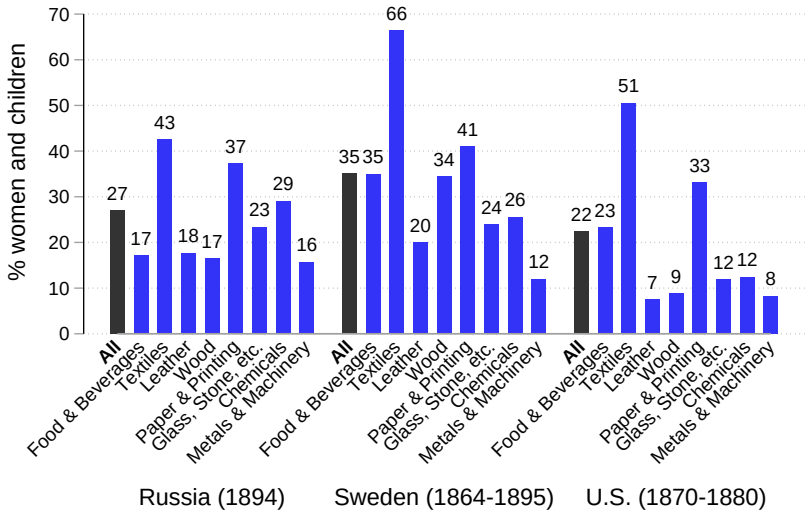
(C) United States

Figure B1: Women and Children by Firm Size

Notes: This figure displays the percentage of workers who were women or children across the firm size distribution in Russia, Sweden, and the United States. Percentages are calculated by dividing total employment of women and children by total employment within each country and size category. Note that the y-axis scales differ across countries, as do the age cutoffs used to define children (see Section 3).



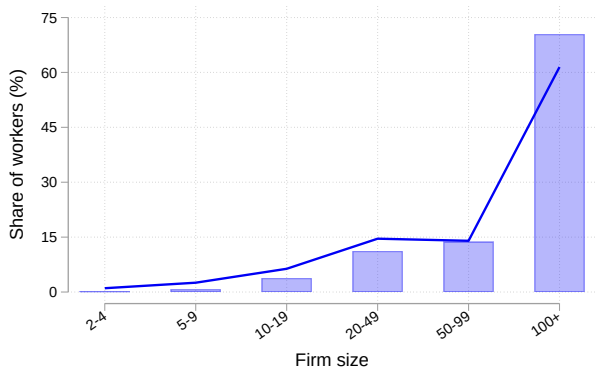
(A) Unweighted



(B) Employment-Weighted

Figure B2: Employment of Women and Children Across Industries

Notes: This figure displays the average percentage of women and children in total employment for all manufacturing firms and broad industry groups in Russia (1894), Sweden (1864–1895), and the United States (1870 and 1880). Panel A reports unweighted firm-level means; Panel B reports employment-weighted means.



(A) Russia



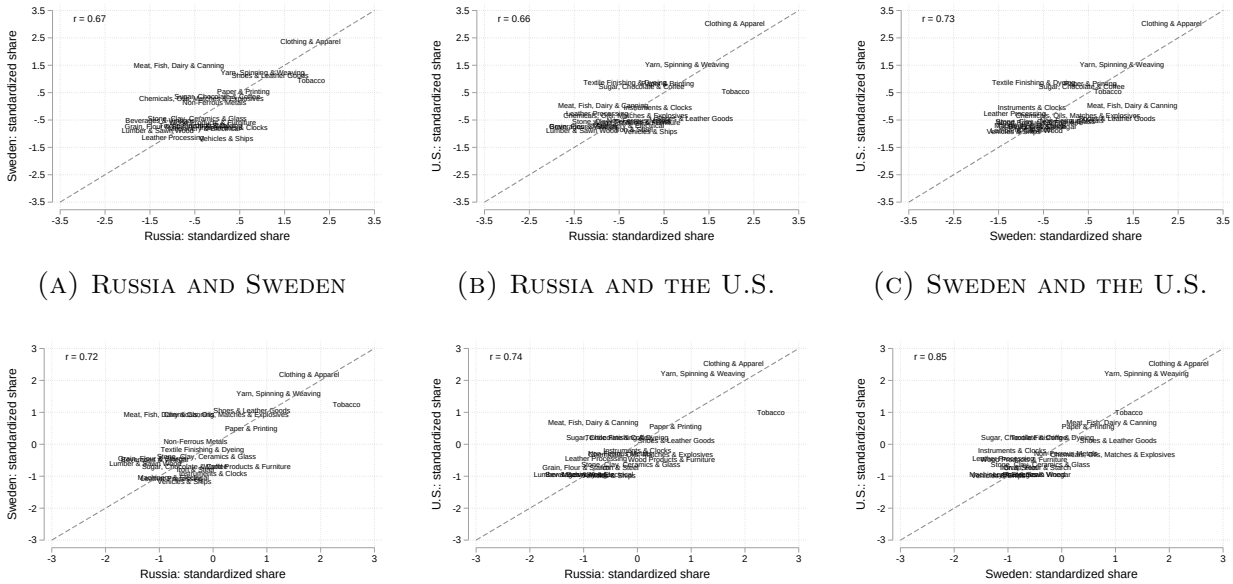
(B) Sweden



(C) United States

Figure B3: Employment of Women and Children Across Firm Sizes

Notes: This figure displays the distribution of women and children across firm-size categories. Bars report each size category's share of total employment of women and children, while lines report each size category's share of total employment. Panel A reports Russia in 1894; Panel B reports Sweden in 1864 and 1895; Panel C reports the United States in 1870 and 1880. Firm-size categories are defined using total employment.



(A) Russia and Sweden (B) Russia and the U.S. (C) Sweden and the U.S.

(D) Russia and Sweden (E) Russia and the U.S. (F) Sweden and the U.S.

FIGURE B4: Employment of Women and Children Across Industries and Countries

Notes: This figure compares standardized industry percentages of women and children across detailed industry groups for each pair of countries. In all panels, values are standardized within country across the detailed industry groups. The top row reports the unweighted mean firm-level percentage within each country-by-detailed-industry cell. The bottom row reports the aggregate detailed-industry percentage, computed as total employment of women and children divided by total employment within each country-by-detailed-industry cell. Labels report detailed industry names; dashed lines denote the 45-degree line.

Table B1: Summary Statistics

	Russia (1894)	Sweden (1864–1895)	U.S. (1870–1880)
Employment			
% women and children	15.81	22.99	9.92
Number of workers	48.12	30.84	12.13
Power use			
Steam power (0/1)	0.42	0.32	0.27
Water power (0/1)	0.11	0.21	0.15
Geography			
Urban (0/1)	0.45	0.48	0.47
Broad industry			
Food & beverages (0/1)	0.42	0.16	0.18
Textiles (0/1)	0.16	0.17	0.15
Leather (0/1)	0.10	0.16	0.05
Wood (0/1)	0.06	0.09	0.26
Paper & printing (0/1)	0.05	0.05	0.03
Glass, stone, etc. (0/1)	0.08	0.16	0.06
Chemicals (0/1)	0.04	0.05	0.03
Machinery & metals (0/1)	0.09	0.16	0.24
Detailed industry			
Grain, flour & starch (0/1)	0.17	0.04	0.11
Sugar, chocolate & coffee (0/1)	0.03	0.01	0.01
Meat, fish, dairy & canning (0/1)	0.04	0.02	0.02
Beverages & vinegar (0/1)	0.17	0.06	0.02
Tobacco (0/1)	0.01	0.04	0.03
Yarn, spinning & weaving (0/1)	0.12	0.07	0.02
Textile finishing & dyeing (0/1)	0.02	0.08	0.00
Clothing & apparel (0/1)	0.02	0.02	0.06
Shoes & leather goods (0/1)	0.01	0.01	0.09
Leather processing (0/1)	0.07	0.15	0.02
Lumber & sawn wood (0/1)	0.04	0.03	0.14
Wood products & furniture (0/1)	0.02	0.04	0.12
Paper & printing (0/1)	0.05	0.05	0.03
Chemicals, oils, matches & explosives (0/1)	0.06	0.06	0.02
Iron & steel (0/1)	0.02	0.06	0.09
Non-ferrous metals (0/1)	0.02	0.02	0.04
Machinery & electrical (0/1)	0.05	0.05	0.04
Vehicles & ships (0/1)	0.01	0.01	0.06
Stone, clay, ceramics & glass (0/1)	0.08	0.16	0.06
Instruments & clocks (0/1)	0.00	0.02	0.01
Observations	16019	72973	255044

Notes: This table reports average outcomes for manufacturing firms in Russia (1894), Sweden (1864–1895), and the United States (1870 and 1880). The sample restricts to firms with at least two and no more than 1,000 workers. The urban row denotes establishments located in cities in Russia and Sweden; for the United States, where establishment-place urban status is not consistently observed, it is a county-level indicator equal to one if more than one-third of the county population lived in cities with at least 2,500 residents.

C Additional OLS Results

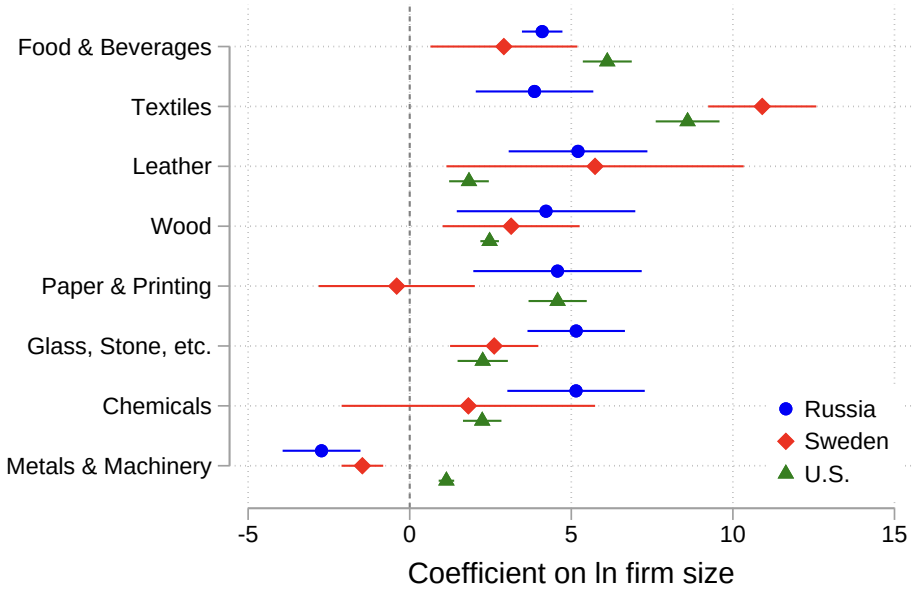


FIGURE C1: FIRM SIZE AND UNSKILLED LABOR ACROSS INDUSTRIES

Notes: This figure displays broad-industry-specific OLS estimates of the coefficient on ln firm size from regressions of the percentage of women and children in total employment on ln firm size. The Russia regressions include region fixed effects, while the Sweden and U.S. regressions include year × region fixed effects. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Industry corresponds to the harmonized set of eight broad industry groups. Horizontal bars denote 95% confidence intervals based on standard errors clustered at the region level.

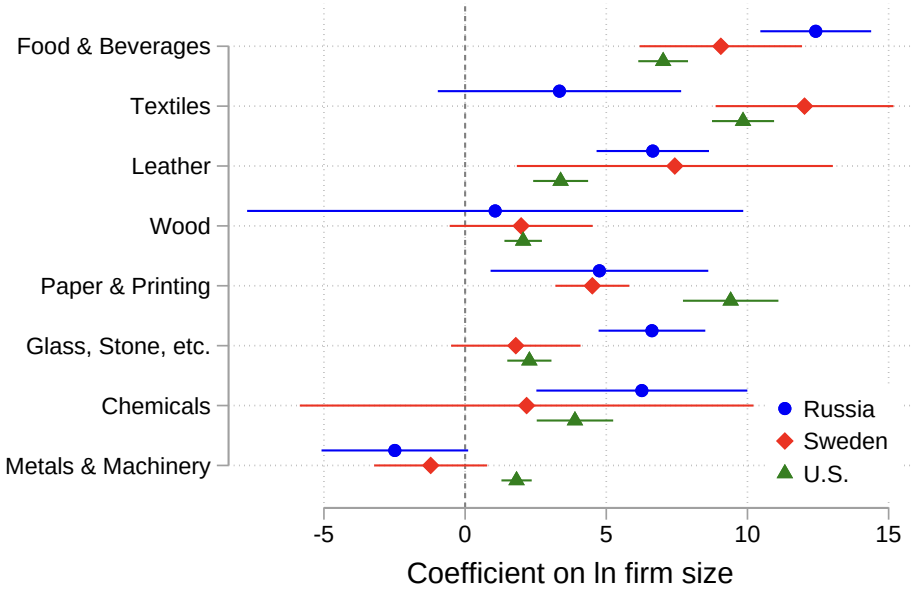


FIGURE C2: FIRM SIZE AND UNSKILLED LABOR ACROSS INDUSTRIES: NON-POWERED FIRMS

Notes: This figure displays broad-industry-specific OLS estimates of the coefficient on ln firm size from regressions of the percentage of women and children in total employment on ln firm size. The sample is restricted to firms that use neither steam nor water power. The Russia regressions include region fixed effects; the Sweden and U.S. regressions include year × region fixed effects. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Bars denote 95% confidence intervals based on standard errors clustered at the region level.

C.1 Additional Robustness

This section provides a set of robustness checks to document that the association between firm size and the employment of women and children is evident in most industries, that it is not sensitive to how I define firm size or a "factory", or pooling women and children, and that it is broadly similar when accounting for differences in firm ownership, geographical location, and firm operation time.

While most traditional accounts focus on deskilling within textiles, Online Appendix Figures B2 and B4 show that women and children were extensively employed in many other industries. Online Appendix Figure C1 shows that the estimated association emerges within virtually all broad industries in all three countries, with the exception of metals and machinery. A lack of a relationship in metals and machinery is consistent with the fact that the rise of machine tools and interchangeable parts within large firms was associated with a growing demand for skilled machinists, blacksmiths, and engineers trained in fitting, measuring, and tool-making (Hounshell, 1984). Indeed, the average firm in the metals and machinery sector employed relatively few women and children in all three countries (Online Appendix Figure B2). To address the more stringent concern that firms employing women and children sorted into particular tasks within broad industry groups, Online Appendix Table C1 estimates the baseline specification separately in five narrowly defined industries that can be matched across all three countries, restricting attention to industries with at least 100 firms in each country, documenting a positive size gradient.

I next show that the results are similar when using alternative ways to measure firm size, or to define a factory. First, adding firm owners to the worker counts accounts for the possibility that the labor input of owners may not have been included in reported worker counts (Sokoloff, 1984; Margo, 2015), which leaves the association largely unchanged as shown in Online Appendix Table C2.

The share of women and children was also more pronounced in large firms and (manu)factories when using typological measures to delineate different firm types as in Sokoloff (1984) and Berger and Ostermeyer (2025a): for example, Online Appendix Table C2 shows that a large factory (defined as a firm with at least 16 workers) had a 5.1 to 7.3 percentage point higher employment share of women and children compared to a smaller firm. Similarly, the share of women and children was substantially greater within manufactories (large firms not relying on inanimate power) and factories (firms relying on inanimate power), compared to artisan shops (small firms not relying on inanimate power). The highest shares of women and children are observed in manufactories, which did not rely on inanimate power but rather relied on achieving productivity gains through division of labor, factory discipline, and improved coordination (Sokoloff, 1984).

Online Appendix Table C2 further shows that results are broadly similar when measuring firm size using nominal output, though the association in Sweden is imprecisely estimated. Relatedly, Online Appendix Table C3 shows that results are similar when restricting the sample to firms with at least 15 workers, which makes the inclusion criteria more similar and accounts for the fact that smaller firms may not have been consistently included in the Russian census (see Section 3).

Online Appendix Table C4 shows that the results are not driven by combining adult women and children since the same positive size gradient is evident when examining women and children separately. Moreover, Online Appendix F uses linked employer-employee data for Swedish printing firms to show that (i) the share of women within a firm is correlated with other measures of worker skills including educational attainment and occupation/task-based measures; and (ii) that large firms employed relatively more workers without a secondary education and in unskilled jobs. Together, these results suggest that the association between unskilled workers and firm size is not driven by a particular definition of unskilled workers.

Online Appendix Table C5 replaces the indicators for the use of steam and water power with reported horsepower per worker from inanimate sources. The negative estimates are consistent with the argument that the transition to inanimate power, particularly steam power, was associated with a reduction in the share of unskilled workers.

I then show that the pattern is robust across geographies and different types of firms. First, Online Appendix Table C6 shows that the positive association between firm size and the share of women and children is evident in both urban and rural samples.[12] Second, the type of firm ownership may be correlated both with firm size and the share of unskilled workers. For example, female owners were more likely to employ female workers than male-owned firms, though not children (Gozen et al., 2025). However, female-owned firms were substantially smaller on average, which would serve to bias upward the share of women in the left tail of the firm size distribution, rather than the right tail. Similarly, larger firms were more likely to be incorporated (Gregg, 2020; Berger and Ostermeyer, 2025b), which could shape the employment of women and children if corporations had more "modern" employment practices. Online Appendix Table C7 uses the fact that the Swedish census recorded information on owners and shows that the association between firm size and the share of women and children is robust to controlling for reported ownership characteristics. Third, Online Appendix Table C8 shows that results are similar both among Russian and U.S. firms that operate part-time and year-round, which may have been correlated with firm

[12]Urbanity is defined based on a firm being located in an urban district in the Swedish and Russian census data and based on information on county urbanization levels from Haines (2010) to define an urban indicator for U.S. counties; I classify firms as urban if they are located in counties where more than a third of the population lives in a city with at least 2,500 inhabitants as urban.

size and the share of unskilled labor (Atack et al., 2002; Gregg and Matiashvili, 2022).

TABLE C1: SELECTED NARROW INDUSTRIES

	Outcome: % women and children		
	Russia (1894)	Sweden (1864–1895)	U.S. (1870–1880)
	(1)	(2)	(3)
Flour/grist milling	1.333***	2.350***	2.578***
	(0.259)	(0.790)	(0.311)
	[2,086]	[1,265]	[20,576]
Leather tanning	3.594***	1.155	0.612**
	(0.734)	(0.795)	(0.297)
	[786]	[10,122]	[4,410]
Sugar refining	3.816*	3.662***	3.250***
	(1.997)	(0.344)	(0.913)
	[186]	[144]	[856]
Glass manufacture	4.574*	1.182	4.662***
	(2.598)	(3.748)	(0.942)
	[144]	[618]	[463]
Tobacco manufacturing	7.230***	5.658***	7.226***
	(1.955)	(1.512)	(0.526)
	[141]	[2,196]	[7,616]
Region × year FE	Yes	Yes	Yes

Notes: Firm-level OLS regressions estimated separately for each country-by-industry sample. The dependent variable is the percentage of women and children in total employment. Each cell reports the coefficient on ln firm size; standard errors clustered at the region level are reported in parentheses, and firms are reported in square brackets. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. All specifications include region-by-year fixed effects; for Russia, which is observed in a single cross section, these fixed effects correspond to region fixed effects. The table restricts to five narrowly defined industries that can be matched across all three countries and have at least 100 firms and positive estimated coefficients in all three countries. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table C2: Alternative Measures of Firm Size

	Outcome: % women and children														
	Russia (1894)					Sweden (1864–1895)					U.S. (1870–1880)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Firm size (ln)	3.218***					2.995***					3.287***				
	(0.397)					(0.837)					(0.181)				
Firm size + 1 (ln)		3.341***					3.232***					3.713***			
		(0.437)					(0.910)					(0.196)			
Large factory (=1)			6.371***					5.115***					7.282***		
			(0.553)					(1.528)					(0.406)		
Manufactory (=1)				8.137***					3.727***					6.118***	
				(0.977)					(0.890)					(0.622)	
Factory (=1)				5.979***					1.645					1.780***	
				(0.934)					(1.358)					(0.304)	
Output (ln)					0.411*					0.102					0.330***
					(0.245)					(0.463)					(0.094)
Region × industry × year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean outcome	15.73	15.73	15.73	15.73	16.37	22.90	22.90	22.90	22.90	23.28	9.99	9.99	9.99	9.99	9.99
Firms	14079	14079	14079	14079	12227	58542	58542	58542	58542	55384	246960	246960	246960	246958	246960

Notes: Firm-level OLS regressions using alternative measures of firm size. The dependent variable is the percentage of women and children in total employment. Large factory equals one for firms with at least 16 workers, following Sokoloff (1984). The industrial-organization type indicators follow Berger and Ostermeyer (2025a): artisan shops are establishments with no steam or water power and fewer than seven workers; manufactories are establishments with no steam or water power and at least seven workers; factories are establishments using steam or water power. Artisan shops are the omitted category in the type-indicator columns. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the region level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE C3: RESTRICTED SAMPLE

	Outcome: % women and children					
	Russia (1894)		Sweden (1864–1895)		U.S. (1870–1880)	
	(1)	(2)	(3)	(4)	(5)	(6)
Firm size (ln)	1.084*	1.543***	2.474**	2.561***	2.812***	3.260***
	(0.570)	(0.588)	(0.973)	(0.784)	(0.213)	(0.255)
Steam power (=1)		-2.073		-0.451		-3.253***
		(1.734)		(1.704)		(0.724)
Water power (=1)		-2.183		-0.414		-1.096*
		(1.631)		(2.330)		(0.639)
Region × industry × year FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean outcome	23.63	23.63	32.07	32.07	21.58	21.58
Firms	6939	6939	16316	16316	35478	35478

Notes: Firm-level OLS regressions. The sample is restricted to firms with at least 15 workers in all countries. The dependent variable is the percentage of women and children in total employment. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the region level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE C4: FEMALE AND CHILD WORKERS

	Russia (1894)		Sweden (1864–1895)		U.S. (1870–1880)	
	Panel A. Outcome: % adult female workers					
	(1)	(2)	(3)	(4)	(5)	(6)
Firm size (ln)	2.496***	2.551***	2.239***	2.567***	2.419***	2.933***
	(0.182)	(0.196)	(0.534)	(0.467)	(0.277)	(0.334)
Steam power (=1)		-0.330		-1.827**		-3.385***
		(0.456)		(0.760)		(0.456)
Water power (=1)		-1.177*		-0.137		-2.289***
		(0.702)		(1.006)		(0.233)
Region × industry × year FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean outcome	8.10	8.10	11.83	11.83	6.46	6.46
Firms	14079	14079	58542	58542	246960	246960
	Panel B. Outcome: % children					
	(1)	(2)	(3)	(4)	(5)	(6)
Firm size (ln)	0.722**	1.121***	0.756	1.217**	0.867***	0.879***
	(0.352)	(0.324)	(0.534)	(0.580)	(0.133)	(0.153)
Steam power (=1)		-2.530***		-2.398***		-0.080
		(0.855)		(0.585)		(0.171)
Water power (=1)		-2.351***		-1.267**		-0.177
		(0.684)		(0.635)		(0.137)
Region × industry × year FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean outcome	7.63	7.63	11.06	11.06	3.52	3.52
Firms	14079	14079	58542	58542	246960	246960

Notes: Firm-level OLS regressions. The dependent variable is the percentage of adult female workers in total employment in Panel A and the percentage of children in total employment in Panel B. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the region level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table C5: Horsepower per Worker

	Outcome: % women and children					
	Russia (1894)		Sweden (1864–1895)		U.S. (1870–1880)	
	(1)	(2)	(3)	(4)	(5)	(6)
Firm size (ln)	3.293***	3.288***	2.810***	2.935***	3.284***	3.278***
	(0.419)	(0.414)	(0.839)	(0.818)	(0.183)	(0.191)
ln HP per worker (std)		-1.558***		-3.518***		-2.109***
		(0.421)		(0.615)		(0.135)
Region × industry × year FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean outcome	16.16	16.16	23.61	23.61	10.00	10.00
Firms	13217	13217	53442	53442	243650	243650

Notes: Firm-level OLS regressions. The dependent variable is the percentage of women and children in total employment. All specifications restrict the sample to firms with observed horsepower per worker. The ln(horsepower per worker + 1) measure is standardized within country. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the region level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table C6: Urban-Rural Split

	Outcome: % women and children					
	Russia (1894)		Sweden (1864–1895)		U.S. (1870–1880)	
	Urban (1)	Rural (2)	Urban (3)	Rural (4)	Urban (5)	Rural (6)
Firm size (ln)	4.401***	3.719***	4.504***	4.363***	4.483***	4.224***
	(0.652)	(0.292)	(0.844)	(0.414)	(0.276)	(0.169)
Steam power (=1)	-3.835**	-2.040***	-5.201***	-1.116	-4.419***	-2.427***
	(1.692)	(0.733)	(1.258)	(1.036)	(0.598)	(0.267)
Water power (=1)	-6.865**	-4.270***	-4.967***	-0.456	-3.514***	-1.043***
	(2.687)	(0.844)	(1.836)	(0.923)	(0.678)	(0.289)
Industry × year FE	Yes	Yes	Yes	Yes	Yes	Yes
Mean outcome	20.56	11.94	26.80	19.50	14.06	6.19
Firms	7192	8827	34835	38123	120731	134313

Notes: Firm-level OLS regressions estimated separately for urban and rural firms. The dependent variable is the percentage of women and children in total employment. The Sweden and U.S. specifications include year × detailed industry fixed effects; the Russia specification includes detailed industry fixed effects because the data are observed in a single cross section. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the region level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table C7: Controlling for Firm Ownership

	Outcome: % women and children			
	(1)	(2)	(3)	(4)
Firm size (ln)	2.995***	3.001***	3.309***	4.038***
	(0.837)	(0.826)	(0.740)	(0.658)
Female owner (=1)		0.468	0.235	0.128
		(1.626)	(1.592)	(1.611)
Partnership (=1)			-0.775	-0.765
			(0.617)	(0.623)
Corporation (=1)			-2.441*	-2.112
			(1.476)	(1.384)
Steam power (=1)				-4.135***
				(0.887)
Water power (=1)				-1.274
				(1.260)
Region × industry × year FE	Yes	Yes	Yes	Yes
Mean outcome	22.90	22.90	22.90	22.90
Firms	58542	58542	58542	58542

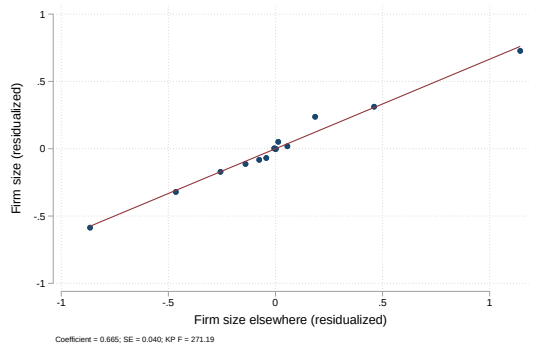
Notes: Firm-level OLS regressions for Swedish manufacturing firms observed in 1864–1895. The dependent variable is the percentage of women and children in total employment. Region corresponds to district (*fögderi*). Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors are clustered at the district level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table C8: Year-Round and Part-Time Firms

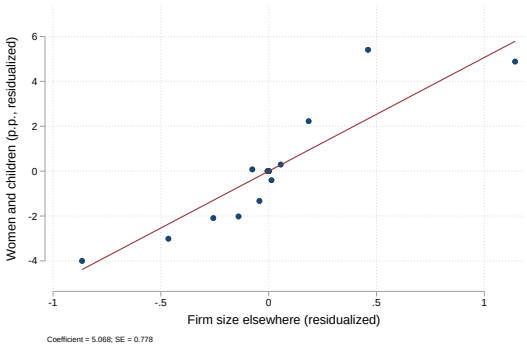
	Outcome: % women and children			
	Russia (1894)		U.S. (1880)	
	Year-round	Part-time	Year-round	Part-time
	(1)	(2)	(3)	(4)
Firm size (ln)	3.251***	3.863***	4.185***	4.615***
	(0.447)	(0.371)	(0.224)	(0.359)
Steam power (=1)	-2.406*	-3.130***	-4.349***	-3.439***
	(1.373)	(0.712)	(0.572)	(0.595)
Water power (=1)	-4.890***	-3.794***	-4.308***	-2.512***
	(0.990)	(0.978)	(0.533)	(0.486)
Industry FE	Yes	Yes	Yes	Yes
Mean outcome	20.89	13.58	10.08	9.51
Firms	4957	10838	76843	56644

Notes: Firm-level OLS regressions estimated separately for year-round and part-time firms. In Russia, year-round firms are defined as those operating at least 280 working days; part-time firms operate fewer than 280 days. In the 1880 U.S. census, year-round firms are defined as those reporting 12 full-time months of operation; part-time firms report fewer than 12 full-time months. The dependent variable is the percentage of women and children in total employment. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors are clustered at the city/*uezd* level in Russia and at the county level in the United States. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

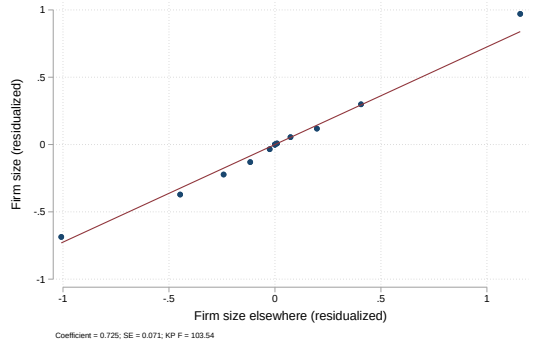
D Additional IV Results



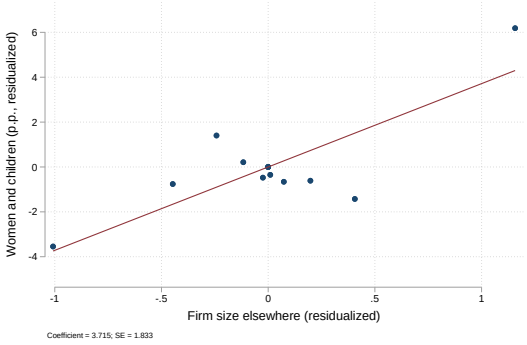
(A) Russia: First stage



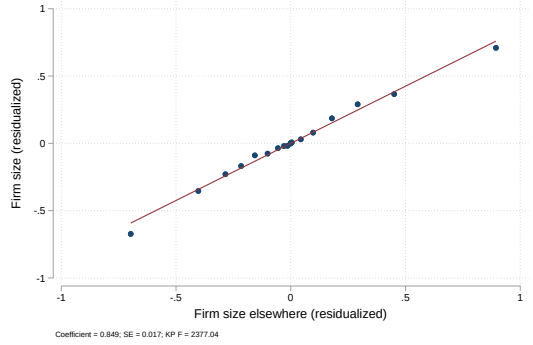
(B) Russia: Reduced form



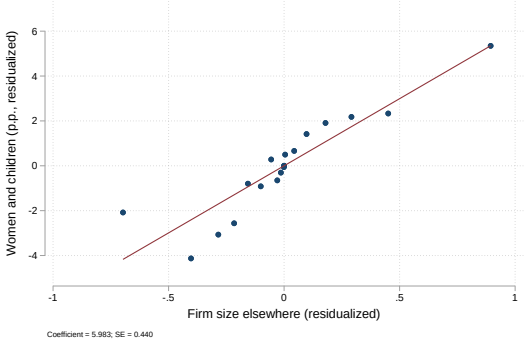
(C) Sweden: First stage



(D) Sweden: Reduced form



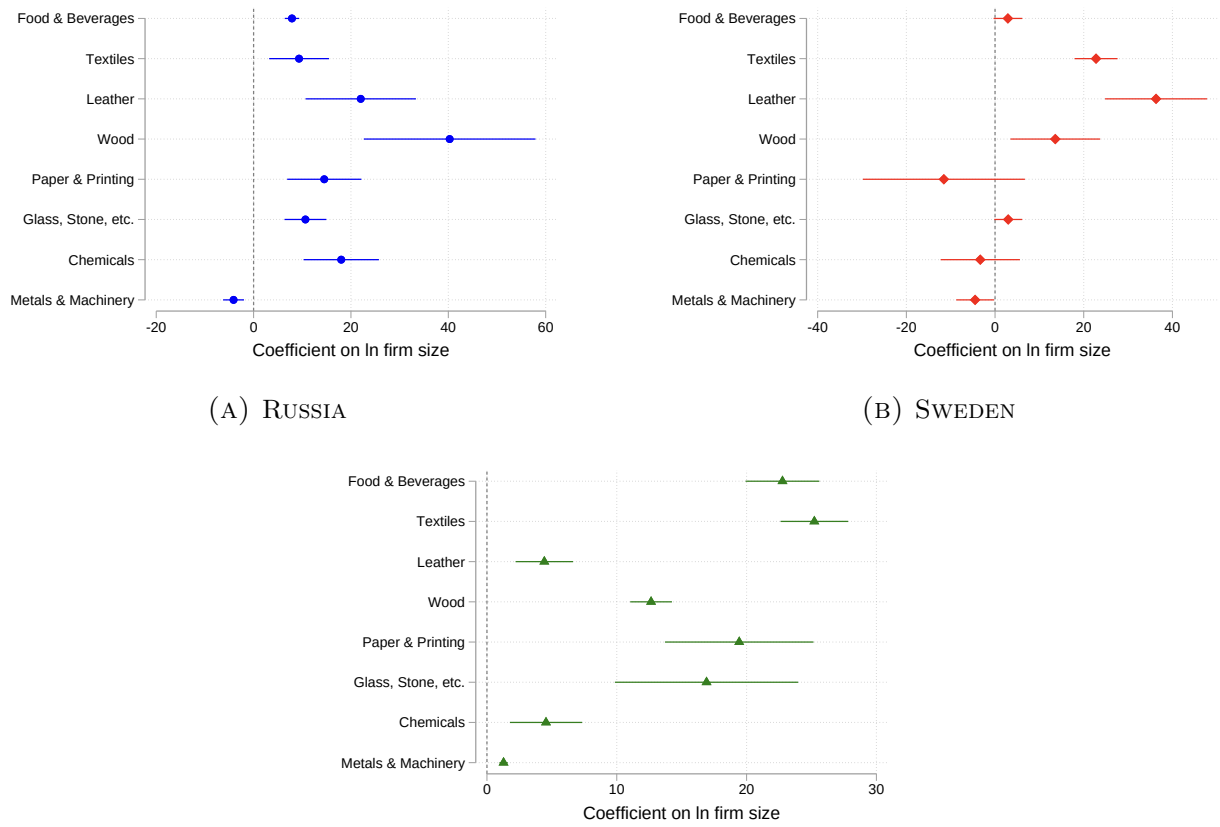
(E) United States: First stage



(F) United States: Reduced form

Figure D1: Instrument Relevance and Reduced Form

Notes: This figure displays binned scatterplots for the baseline IV specifications without IV controls. Panels A, C, and E show the first-stage relationship between own-firm ln size and average ln firm size in the same granular industry in other regions. Panels B, D, and F show the corresponding reduced-form relationship for the percentage of workers who are women or children. All variables are residualized using the fixed effects in the baseline specification. Each panel contains 20 equal-frequency bins; the solid line is estimated using the underlying firm-level observations. Panel annotations report the regression coefficient and standard error clustered at the baseline region level; the first-stage panels also report the Kleibergen–Paap F-statistic. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively.



(A) Russia (B) Sweden

(C) United States

Figure D2: Firm Size and Unskilled Labor: IV Estimates

Notes: This figure displays broad-industry-specific IV estimates of the coefficient on ln firm size from regressions of the percentage of women and children in total employment on ln firm size. Panels A–C report estimates for Russia, Sweden, and the United States, respectively. The instrument is average ln firm size in the same granular industry in other regions. The Russia regressions include region fixed effects, while the Sweden and U.S. regressions include year × region fixed effects. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Industry corresponds to the harmonized set of eight broad industry groups. Horizontal bars denote 95% confidence intervals based on standard errors clustered at the region level.

Table D1: Firm Size, Technology Use, and Unskilled Labor: 2SLS Estimates

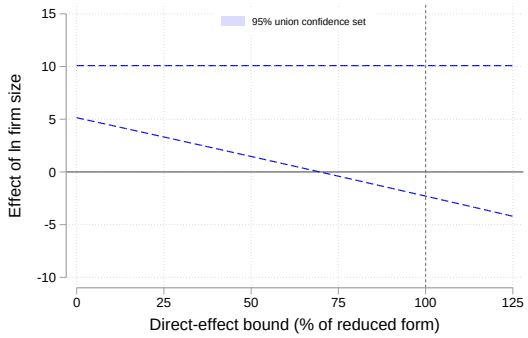
	Outcome: % women and children														
	Russia (1894)					Sweden (1864–1895)					U.S. (1870–1880)				
	RF (1)	2SLS (2)	2SLS (3)	2SLS (4)	2SLS (5)	RF (6)	2SLS (7)	2SLS (8)	2SLS (9)	2SLS (10)	RF (11)	2SLS (12)	2SLS (13)	2SLS (14)	2SLS (15)
Firm size elsewhere (ln)	5.068***					3.715**					5.983***				
	(0.778)					(1.833)					(0.440)				
Firm size (ln)		7.619***	7.493***	9.222***	7.426***		5.124**	3.608**	5.880**	3.631**		7.046***	5.266***	10.906***	5.257***
		(1.262)	(1.122)	(1.380)	(1.102)		(2.350)	(1.601)	(2.617)	(1.556)		(0.600)	(0.450)	(0.959)	(0.442)
Steam power (=1)				-7.814***	-5.517***				-6.973***	-3.837**				-11.063***	-4.318***
				(0.912)	(0.788)				(2.548)	(1.784)				(1.229)	(0.505)
Water power (=1)				-5.691***	-5.262***				-3.143	-0.855				-5.589***	-2.310***
				(0.913)	(0.942)				(2.071)	(1.929)				(0.510)	(0.289)
Region × industry × year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV controls	No	No	Yes	No	Yes	No	No	Yes	No	Yes	No	No	Yes	No	Yes
Kleibergen-Paap F-statistic	—	271.19	246.78	170.31	272.04	—	103.54	66.56	113.40	112.12	—	2377.04	1099.57	1655.16	1966.36
Firms	13883	13883	13845	13883	13845	55746	55746	55670	55746	55670	246925	246925	246923	246925	246923

Notes: Firm-level reduced-form OLS and 2SLS regressions. The dependent variable is the percentage of workers who are women or children. Firm size is instrumented using average ln firm size among firms in the same granular industry located in other regions. IV controls are residual child/female employment among firms in the same granular industry in other regions, where residuals net out ln firm size, own-firm steam and water power, and region-by-detailed-industry fixed effects, as well as steam and water shares among firms in the same granular industry in other regions. For Sweden and the United States, leave-region-out measures pool all sample years within country. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Country-specific granular industries are used to construct the leave-region-out measures; absorbed industry fixed effects use the harmonized set of 20 detailed industry groups. Standard errors clustered at the region level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

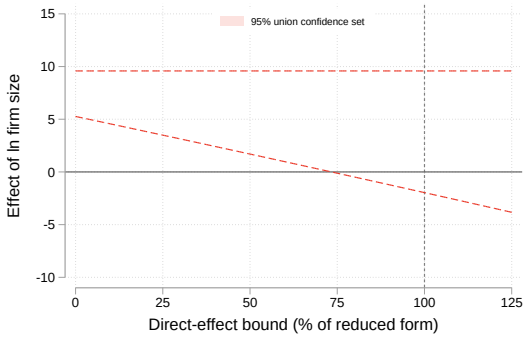
Table D2: Weak-Instrument-Robust Inference

	Russia (1894)	Sweden (1864–1895)	U.S. (1870–1880)
	(1)	(2)	(3)
Firm size (ln)	7.619***	5.124**	7.046***
	(1.262)	(2.350)	(0.600)
Region × industry × year FE	Yes	Yes	Yes
Anderson–Rubin 95% confidence set	[5.234, 10.229]	[0.155, 9.610]	[5.899, 8.254]
Anderson–Rubin p-value ($\beta = 0$)	<0.001	0.044	<0.001
Kleibergen–Paap F-statistic	271.19	103.54	2377.04
Mean outcome	15.52	21.20	9.98
Firms	13883	55746	246925

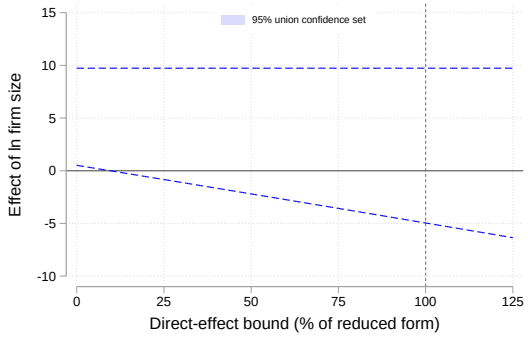
Notes: Firm-level baseline 2SLS regressions of the percentage of workers who are women or children. Firm size is instrumented using average ln firm size among firms in the same granular industry located in other regions. For Sweden and the United States, the instrument pools all sample years within country. The table reports conventional 2SLS point estimates and standard errors in parentheses, 95% Anderson–Rubin confidence sets, and Anderson–Rubin p-values for the null hypothesis that the coefficient on firm size is zero. Both conventional and Anderson–Rubin inference cluster standard errors at the baseline region level. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Country-specific granular industries are used to construct the instrument; absorbed industry fixed effects use the harmonized set of 20 detailed industry groups. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.



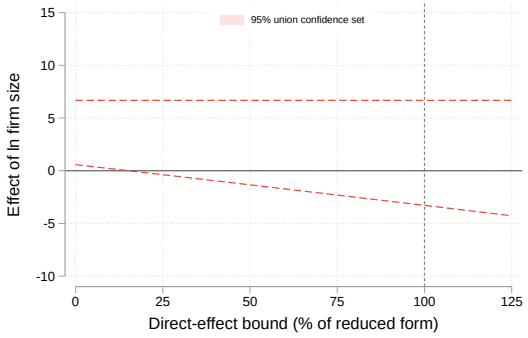
(A) Russia: Baseline



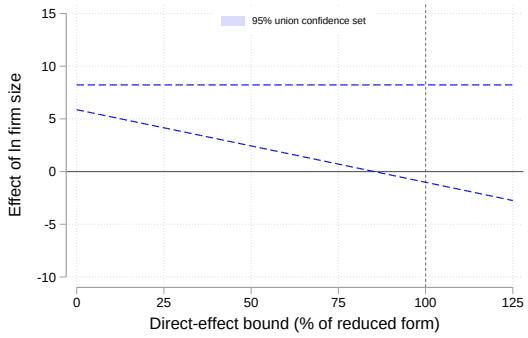
(B) Russia: Full IV controls



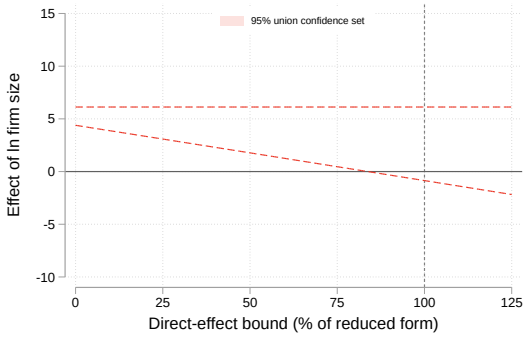
(C) Sweden: Baseline



(D) Sweden: Full IV controls



(E) United States: Baseline

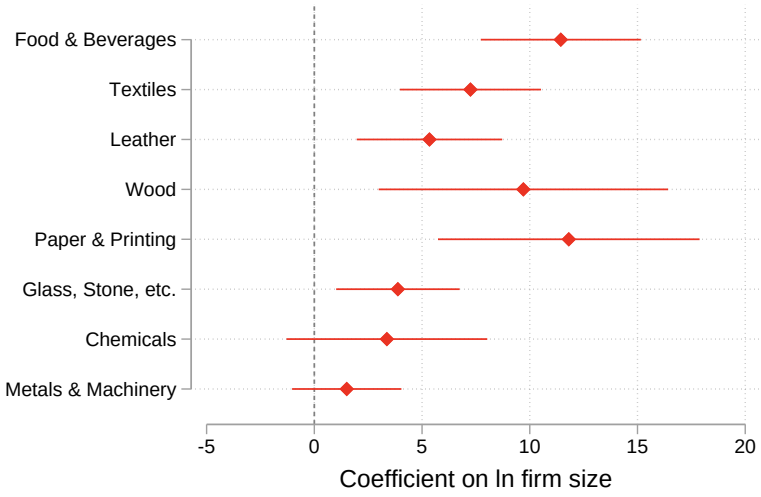


(F) United States: Full IV controls

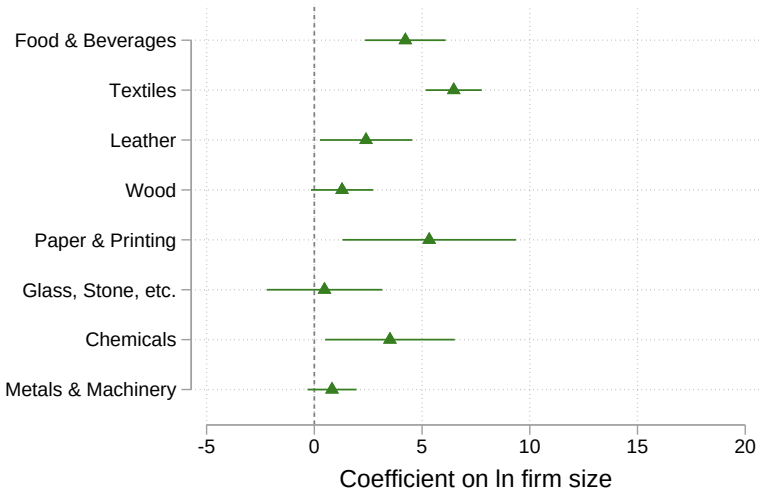
Figure D3: Sensitivity to Violations of Exclusion Restriction

Notes: This figure displays 95% union confidence sets from plausibly-exogenous 2SLS specifications. Panels A, C, and E report the baseline specifications for Russia, Sweden, and the United States, respectively; Panels B, D, and F report the corresponding specifications with full IV controls. The horizontal axis gives the upper bound on a same-sign direct effect of the instrument as a percentage of its reduced-form coefficient. For each value of the bound, the shaded region is the union of conventional 95% confidence intervals obtained by allowing the direct effect to range between zero and that bound. The vertical dashed line denotes a bound equal to the full reduced-form coefficient. Full IV controls include own-firm steam- and water-power indicators and residual child/female employment and steam- and water-power shares among firms in the same granular industry in other regions. All specifications absorb the fixed effects used in the baseline IV regressions. Standard errors are clustered at the baseline region level: city/*uezd* in Russia, district (*fögderi*) in Sweden, and county in the United States.

E Additional Panel Results



(A) Sweden



(B) United States

Figure E1: Panel OLS Regressions: By Industry

Notes: This figure displays broad-industry-specific panel estimates of the coefficient on ln firm size from regressions of the percentage of women and children in total employment on ln firm size. Panel A reports estimates for linked Swedish firms observed in 1864–1895; Panel B reports estimates for linked U.S. firms observed in 1870 and 1880. Both samples exclude firms using steam or water power when first observed, and both specifications include firm and year fixed effects. Industry corresponds to the harmonized set of eight broad industry groups. Horizontal bars denote 95% confidence intervals based on standard errors clustered at the firm level.

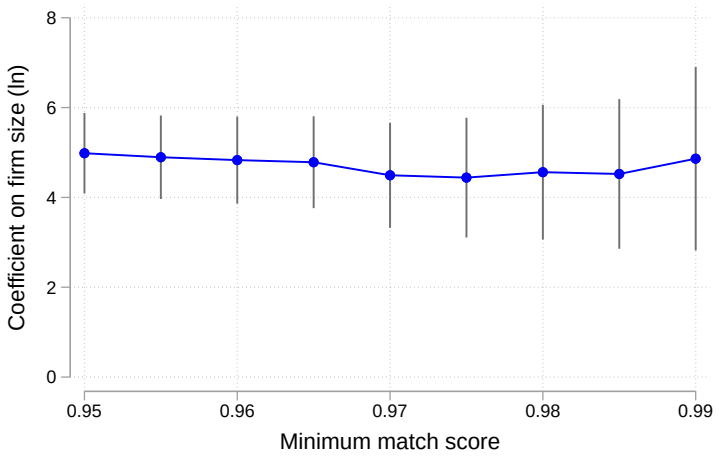
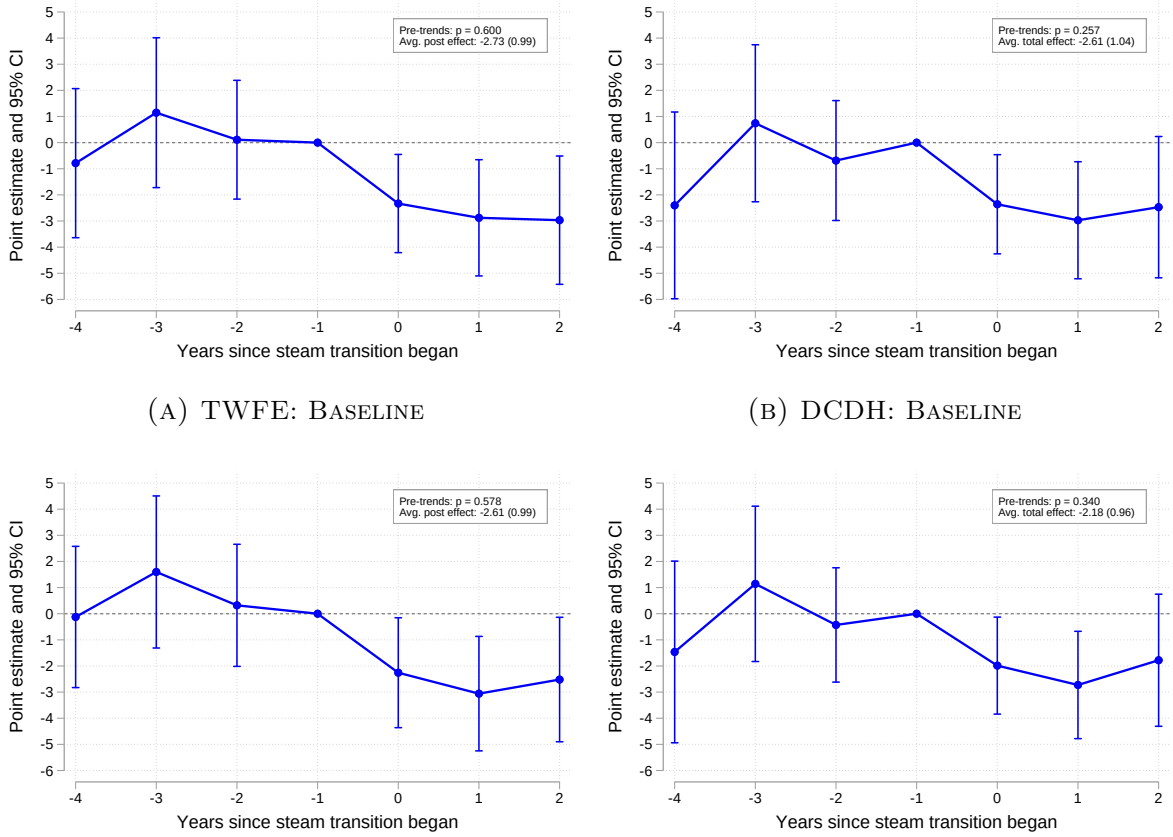


FIGURE E2: PANEL OLS REGRESSIONS: MATCH QUALITY IN THE U.S. LINKED SAMPLE

Notes: This figure plots the coefficient on ln firm size and 95% confidence intervals from panel regressions of the percentage of women and children on ln firm size, restricting the U.S. linked sample to matches with a bigram similarity score above the indicated threshold. The baseline threshold used in the main analysis is 0.95. All specifications include firm fixed effects and year × county × broad industry fixed effects. Industry corresponds to the harmonized set of eight broad industry groups. Standard errors are clustered at the firm level.

E.1 Event-Study Estimates

Figure E3 presents conventional two-way fixed-effects event-study estimates alongside estimates obtained using the dynamic difference-in-differences estimator of de Chaisemartin and D'Haultfœuille (2026). Online Appendix Figure E3 includes a barebones specification and a specification that flexibly controls for factors that may have shaped the adoption of steam. Across all four specifications, joint tests fail to reject the null that the pre-treatment coefficients are zero. After the transition to steam, the share of women and children declines sharply: the average post-treatment estimates range from -2.73 to -2.18 percentage points. These estimates are broadly similar in magnitude to the standard difference-in-differences estimate reported in Table 1, Panel C, Column 5.



(A) TWFE: Baseline (B) DCDH: Baseline

(C) TWFE: Controls (D) DCDH: Controls

Figure E3: The Transition to Steam Power and Unskilled Labor

Notes: This figure displays establishment-level event-study estimates of changes in the percentage of women and children around the transition to steam power in Swedish manufacturing firms. Event time zero is defined as one year before steam use is first reported, allowing for installation and reporting lags; the treatment indicator remains equal to one thereafter. Panels A and C use the eventdd estimator, with endpoints binned at $t \leq -4$ and $t \geq 2$ and $t = -1$ omitted. Panels B and D use the dynamic difference-in-differences estimator of de Chaisemartin and D'Haultfœuille (2026), implemented by did_multiplegt_dyn, and plot the corresponding placebo and effect horizons after residualizing the outcome on the controls and fixed effects used in the respective panel. All panels control for contemporaneous ln total employment and include firm and year fixed effects. Panels C and D additionally include county-by-year and detailed-industry-by-year fixed effects. Firm controls in Panels C and D are entry ln total employment, an indicator for corporate ownership at entry, and the entry percentage of women and children, each interacted with year fixed effects. Industry corresponds to the harmonized set of 20 detailed industry groups. Each panel reports the p-value from a joint test of the displayed pre-treatment coefficients and a post-treatment summary, with its standard error in parentheses. Panels A and C report the equal-weight average of the eventdd estimates for $t = 0, 1, 2$. Panels B and D report the average total effect produced by did_multiplegt_dyn across the displayed effect horizons. Connected markers denote point estimates. Vertical bars denote 95% confidence intervals based on standard errors clustered at the firm level.

Table E1: Panel Estimates: Additional Controls

	Outcome: % women and children							
	Sweden, 1864–1895				United States, 1870–1880			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Firm size (ln)	5.972***	5.819***	6.180***	6.043***	4.288***	4.570***	4.549***	4.973***
	(0.694)	(0.652)	(0.691)	(0.647)	(0.366)	(0.282)	(0.384)	(0.306)
Steam power (=1)			-2.392**	-2.329**			-2.794***	-3.013***
			(0.960)	(0.944)			(0.968)	(0.827)
Water power (=1)			0.962	0.426			-4.417**	-6.851***
			(1.190)	(1.213)			(2.105)	(1.269)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County × year FE	No	Yes	No	Yes	No	Yes	No	Yes
Industry × year FE	No	Yes	No	Yes	No	Yes	No	Yes
Firm controls × year FE	No	Yes	No	Yes	No	Yes	No	Yes
Mean outcome	25.34	25.35	25.34	25.35	14.16	14.46	14.16	14.46
Observations	17787	17744	17787	17744	15676	15234	15676	15234
Firms	2518	2517	2518	2517	7838	7617	7838	7617

Notes: Firm-level OLS regressions for linked Swedish manufacturing firms observed in 1864–1895 and linked U.S. firms observed in 1870 and 1880. The dependent variable is the percentage of workers who are women or children. In the Swedish power-controlled specifications (columns 3–4), the steam and water indicators switch to one when adoption of the respective technology likely began, whereas in the U.S. specifications (columns 7–8) they capture reported power use in each census year. Firm controls are baseline ln firm size, an indicator for corporate ownership, and the baseline percentage of women and children, each interacted with year fixed effects where indicated. County corresponds to *län* in Sweden and county in the United States. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the firm level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table E2: Panel OLS Regressions: Full-Time Firms

	Outcome: ln FTE annual wages per worker			
Sample:	All	No power	All	All
	(1)	(2)	(3)	(4)
Firm size (ln)	-0.121***	-0.132***	-0.136***	-0.143***
	(0.012)	(0.017)	(0.013)	(0.013)
Steam power (=1)			0.115***	0.121***
			(0.024)	(0.025)
Water power (=1)			0.068	0.039
			(0.048)	(0.049)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County × year FE	No	No	No	Yes
Industry × year FE	No	No	No	Yes
Firm controls × year FE	No	No	No	Yes
Mean outcome	6.00	5.95	6.00	6.01
Observations	12156	7054	12156	11750
Firms	6078	3527	6078	5875

Notes: Firm-level OLS regressions for linked U.S. firms observed in 1870 and 1880 that operated full-time in both years and had valid wage inputs. The dependent variable is the log of full-time-equivalent annual wages per worker. The no-power sample consists of firms that used neither steam nor water power in either year. Baseline firm controls, interacted with year fixed effects, include ln firm size, an indicator for corporate ownership, and the baseline percentage of women and children. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the firm level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table E3: Panel OLS Regressions: Higher-Quality Links

	Outcome: ln FTE annual wages per worker			
Sample:	All	No power	All	All
	(1)	(2)	(3)	(4)
Firm size (ln)	-0.211***	-0.192***	-0.219***	-0.240***
	(0.018)	(0.023)	(0.019)	(0.019)
Steam power (=1)			0.110***	0.134***
			(0.031)	(0.030)
Water power (=1)			0.071	0.065
			(0.054)	(0.054)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
County × year FE	No	No	No	Yes
Industry × year FE	No	No	No	Yes
Firm controls × year FE	No	No	No	Yes
Mean outcome	5.96	5.93	5.96	5.98
Observations	9678	4434	9678	9186
Firms	4839	2217	4839	4593

Notes: Firm-level OLS regressions for linked U.S. firms observed in 1870 and 1880 with valid wage inputs and a composite match score of at least 0.99. The dependent variable is the log of full-time-equivalent annual wages per worker. The no-power sample consists of firms that used neither steam nor water power in either year. Baseline firm controls, interacted with year fixed effects, include ln firm size, an indicator for corporate ownership, and the baseline percentage of women and children. Industry corresponds to the harmonized set of 20 detailed industry groups. Standard errors clustered at the firm level are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

F Alternative Measures: Skills and Organizational Change

This section uses linked employer-employee data for the Swedish printing industry assembled by Burnette and Stanfors (2020) to (i) document that other measures of worker skills beyond the share of women and children correlate with firm size; and (ii) provide more direct evidence on organizational differences across the firm size distribution. The printing industry is a useful setting because women and children made up a high share of employment in this industry in both Europe and the United States (Online Appendix Figure B2). The data are based on the 1902/03 Swedish Board of Commerce survey of printing and allied trades, which collected separate employer and employee data. I aggregate workers to firms and restrict the sample to firms with 2–1,000 workers as in the main analysis, leaving about 7,900 workers in 321 firms.

F.1 Firm Size and Skills in the Printing Industry

Although women and children constitute a historically relevant measure of unskilled workers, it is an open question whether their employment correlates with other measures of worker skills that are not available in the historical censuses used in the main analysis.

Using the linked employer-employee data for the Swedish printing industry, I perform two tests. First, I examine whether the share of women and children is correlated with alternative measures of worker skills. Second, I ask whether larger firms employ relatively more unskilled workers using these alternative measures.

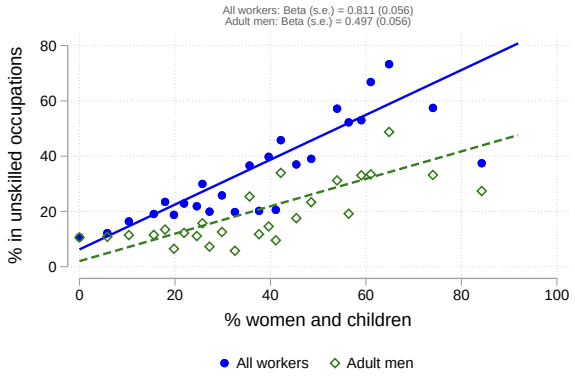
I construct the percent of workers who are women or children, where children are workers younger than 18 to align with the Swedish census data used in the main analysis. I then use two alternative skill measures: the percent of workers in unskilled occupations and the percent with any secondary education. For each measure, I calculate the firm-level percentage among all workers and separately among men aged 18 or older. I code unskilled occupations from the original occupation strings and detailed occupation groups and separate recognized craft, supervisory, and skilled printing jobs from unskilled work.[13]

Figure F1 provides both tests and reports outcomes for all workers and, separately, for men aged 18 or older. Panels A and B show that firms with more women and children have substantially higher shares of workers in unskilled occupations and a lower share of workers with a secondary education. The association is similar, though naturally somewhat weaker,

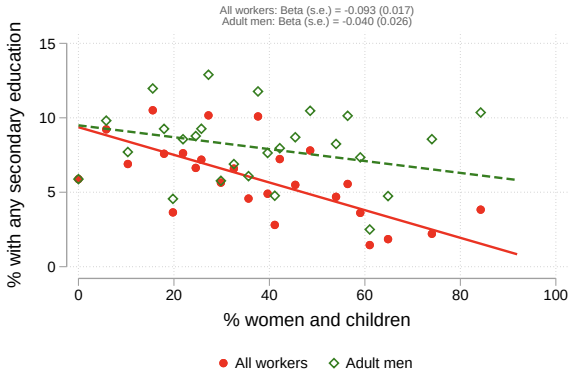
[13] In the context of the printing industry it is relatively straightforward to delineate skilled and unskilled jobs: Compositors, typesetters, skilled pressmen, stereotypers, lithographers, photoengravers, full bookbinders, and supervisors are classified as skilled; by contrast, press feeders and takers-off, composition-room support workers, simple press workers, typefounding and lithographic support workers, simple bookbinding and finishing workers, packing, cleaning, carrying, and general labor are classified as unskilled.

when considering the share of adult men in unskilled occupations and the share of adult men who lack a secondary education, which suggests that the association is not purely driven by compositional differences due to the employment of women and children. Panels C and D compare the same skill measures across the firm size distribution showing that larger firms have higher unskilled shares both overall and among adult men, while the association with the share of workers with a secondary education is negative.

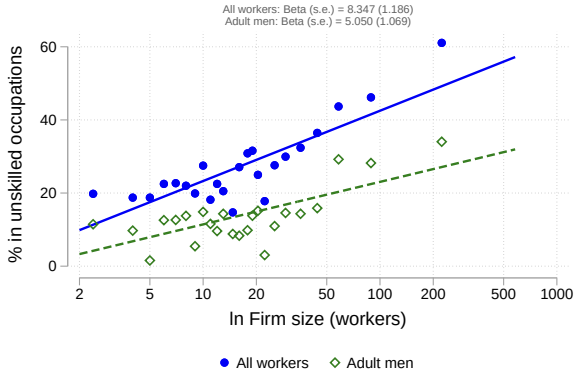
Taken together, these results suggest that the share of women and children is a useful proxy for unskilled labor in the nineteenth and early twentieth centuries. Not only did women and children constitute an important source of unskilled labor and feature prominently in contemporary debates over deskilling, but the measure is also strongly correlated with alternative measures of worker skill based on education and occupational tasks.



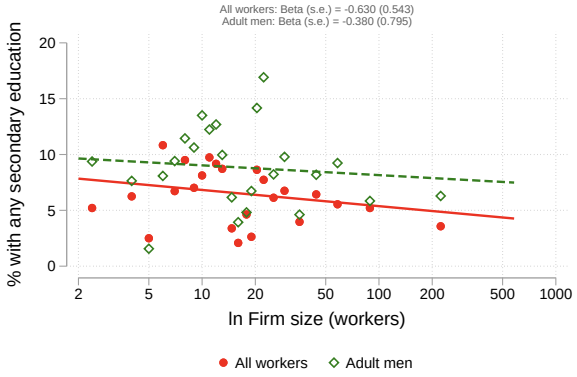
(A) Women and Children vs. Unskilled Jobs



(B) Women and Children vs. Education



(C) Firm Size and Unskilled Jobs



(D) Firm Size and Worker Education

Figure F1: Women and Children vs. Alternative Skill Measures

Notes: This figure displays binned scatterplots for Swedish printing firms using linked employer-employee data from Burnette and Stanfors (2020). The unit of observation is the firm, and the sample is restricted to firms with 2–1,000 workers. Panels A and B plot the percent of workers in unskilled occupations and the percent with any secondary education against the percent of workers who are women or children. Panels C and D plot the same outcomes against ln firm size, with x-axis labels reported in worker counts. In each panel, filled circles and solid fitted lines report outcomes for all workers; hollow green diamonds and dashed fitted lines report outcomes for men aged 18 or older. All panels use 30 bins. Points in Panels A and B are firm-size-weighted binned means; best-fit lines and reported regression statistics use the same firm-size weights. Panels C and D use unweighted firm-level binned means and unweighted firm-level regressions.

F.2 Firm Size and Organizational Change in the Printing Industry

As discussed in Section 4.3, firm size may be associated with three broad organizational changes: a greater division of labor and finer decomposition of tasks, a more tightly regulated work regime and factory discipline, and more developed managerial hierarchies. The survey of the printing industry describes how the organizational structure of large and small firms differed in such dimensions:

> "Before the printing trade became a factory industry during the second half of the nineteenth century, there were only two groups of workers, compositors and pressmen. Although this specialization had existed since the seventeenth century [...], these groups do not appear to have always been clearly separated; instead, the same worker was commonly skilled in both composition and printing. There was no division of labor: each job was assigned to a worker, who completed it alone or with a companion (*spåne*). The same is still true today in small printing offices, where the proprietor usually works at the cases and is confined to small, occasional orders. In large printing offices, by contrast, the division of labor has brought about a far-reaching specialization [...]"[14]

I here use different measures of occupational structure, working time and scheduling, and supervision to examine how they vary across large and small printing firms. Table F1 presents estimates from firm-level OLS regressions where I regress measures of organizational structure on log employment for establishments with 2–1,000 workers, controlling for whether a firm is located in one of the three largest cities.

Panel A measures occupational diversity and task decomposition by using normalized entropy across detailed occupational groups, the number of occupations represented in a firm, the ratio of support to craft workers, and the shares of apprentices and compositors, which captures differences in the division of labor (Kommerskollegium, 1909, pp. 59–60). Larger establishments had substantially more differentiated occupational structures and a greater number of occupations represented, as well as a greater number of support relative to craft workers. At the same time, the share of apprentices is lower, while the estimated

[14] The Swedish original reads: "Innan boktryckerinäringen under senare hälften af 1800-talet öfvergick till fabriksindustri, funnos endast två grupper af arbetare inom densamma, sättare och tryckare, men ehuru denna specialisering förekom redan på 1600-talet [...] synas dock ej heller dessa grupper alltid hafva varit klart åtskilda, utan var det snarare vanligt, att samma arbetare var kunnig i både sättning och tryckning. Ingen fördelning af arbetet ägde rum, utan hvarje särskildt arbete utlämnades till en arbetare, som ensam eller tillsammans med någon kamrat (»spåne«) fullbordade detsamma. Samma är förhållandet ännu i dag vid de små tryckerierna, där arbetsgifvaren vanligen själf står vid kasten och är hänvisad till smärre, tillfälliga beställningar. I de stora tryckerierna däremot har arbetsfördelningen medfört en långt drifven specialisering [...]" (Kommerskollegium, 1909, p. 189).

association with the share of compositors is negative but statistically insignificant. Broadly, the pattern is consistent with larger establishments combining a wider set of specialized occupations with relatively more unskilled auxiliary work.

Panel B measures the work regime using establishment means of worker-reported usual weekly hours and annual overtime hours, together with indicators for whether any worker reports shift, night, or Sunday work. These measures capture both the duration and scheduling of work, including arrangements outside ordinary daytime hours. A doubling of employment is associated with additional overtime hours per year and increases in the probability that some worker reports shift, night, or Sunday work. The association with usual weekly hours is small and statistically insignificant.[15]

Panel C measures supervision and employment stability using indicators for any recorded foreman and any *Faktor*, the number of recorded foremen, workers per recorded foreman among establishments with one, and average worker tenure.[16] The supervision measures proxy for supervisory roles and their span of control, while tenure captures the stability of the employment relationship. The estimates show that larger establishments more often employed foremen and a *Faktor*. Among establishments with a foreman, firm size is also associated with a greater number of workers per foreman, while average tenure also increases with firm size.

Taken together, the results show that larger printing establishments differed systematically in terms of occupational diversity, work regime, and supervision.

[15]The report indicates that shift, night, and Sunday work was concentrated in newspaper printing, so the associations may partly reflect differences in establishments' production mix (Kommerskollegium, 1909, pp. 106–108).

[16]The *Faktor* indicator follows the report's occupational classification, which lists *Faktorer* together with foremen who also participated in production (Kommerskollegium, 1909, p. 59). Foremen who did not directly participate in the work were classified as management staff and did not complete the worker questionnaire (Kommerskollegium, 1909, p. 55).

Table F1: Firm Size and Organization

	Occ. entropy	# occupations	Support/craft	Apprentices (%)	Compositors (%)
	(1)	(2)	(3)	(4)	(5)
Panel A. Task decomposition					
Firm size (ln)	0.091***	2.825***	0.195***	-2.959**	-2.567
	(0.008)	(0.146)	(0.072)	(1.253)	(1.767)
Big-city control	Yes	Yes	Yes	Yes	Yes
Mean outcome	0.427	5.831	0.693	29.485	49.604
Number of firms	320	320	311	321	321
	Weekly hours	OT hours/year	Any shift (=1)	Any night (=1)	Any Sunday (=1)
	(6)	(7)	(8)	(9)	(10)
Panel B. Work regime					
Firm size (ln)	0.267	7.241***	0.080***	0.095***	0.071***
	(0.257)	(1.312)	(0.019)	(0.021)	(0.019)
Big-city control	Yes	Yes	Yes	Yes	Yes
Mean outcome	56.761	18.512	0.097	0.121	0.078
Number of firms	320	321	321	321	321
	Any foreman (=1)	Any factor (=1)	# foremen	Workers/foreman	Mean tenure
	(11)	(12)	(13)	(14)	(15)
Panel C. Managerial hierarchy and formalization					
Firm size (ln)	0.128***	0.041*	0.421***	20.034***	0.952***
	(0.024)	(0.021)	(0.059)	(2.795)	(0.166)
Big-city control	Yes	Yes	Yes	Yes	Yes
Mean outcome	0.545	0.212	0.738	18.090	5.086
Number of firms	321	321	321	175	320

Notes: Establishment-level OLS regressions using worker-level returns from Swedish printing and allied-trades establishments surveyed in 1902/03. The sample includes establishments with 2–1,000 workers. Each column regresses the indicated organizational outcome on ln establishment employment and includes a big-city control, which equals one for establishments in Stockholm, Göteborg, or Malmö. Entropy is normalized Shannon entropy across 26 detailed occupation groups and is divided by ln(26). Occupations is the number of represented detailed groups; both outcomes exclude the establishment without a valid detailed occupation code. Support/craft is the number of auxiliary and simple-task workers—such as composing-room assistants, press feeders, handling and finishing workers, lithographic assistants, and general labor—divided by the skilled craft core, including typesetters, pressmen, stereotypers, type founders, engravers, lithographers, bookbinders, and gilders; establishments without a craft worker are excluded from that column. Apprentices and compositors are percentages of the roster; compositors belong to groups 2–4. Weekly hours and annual overtime hours are establishment means. The shift, night, and Sunday indicators equal one if any worker reports the corresponding arrangement. Any foreman indicates at least one respondent coded as a foreman, foremen is the number of such respondents, and workers per foreman is defined only for establishments with at least one. Any factor equals one if any worker's reported occupation contains the title *Faktor*. The survey lists *Faktorer* with foremen among workers who also participated in production; foremen who did not participate directly in production did not complete employee returns. Mean tenure is measured in years with the current employer. Industry and survey year are fixed by construction. The estimates describe cross-sectional associations. Robust standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

G Firm Size and Deskilling in Brickmaking

Brickmaking is a useful case study for examining the relationship between firm size and the employment of unskilled labor. In particular, bricks were more standardized than many manufactured goods and the key production steps were shared across product types—for example, common bricks, facing bricks, and paving bricks—and in both large and small firms. For ordinary handmade bricks, the basic sequence of production also changed less than in many other industries over the nineteenth century, even as clay preparation, kiln design, and drying arrangements saw gradual improvement (Hounsell, 2022). Clay was first extracted, weathered, and prepared by working it into a plastic consistency, either by hand or using a pug mill (Dobson, 1850). The prepared clay was then hand-moulded into individual bricks by a moulder, who pressed the clay into a wetted or sanded wooden mold. An off-bearer carried the filled mold to a drying area, where the green bricks were left to harden before being stacked and fired in a clamp or kiln. The moulder was the most skilled worker in the process, but depended on a team of assistants to supply clay, remove filled molds, and manage the drying and firing stages (Dobson, 1850; Hounsell, 2022).

Among non-mechanized yards, the key difference between small and large brickworks was organizational rather than technological. Small brickyards were typically operated by a single moulder and a few helpers, often family members. Large urban brickworks employed the same hand-moulding techniques but organized production around gangs—teams of roughly six workers, including women and children alongside adult men (Hounsell, 2022). Women typically served the moulder by preparing and transporting clay to the moulding table, while children performed ancillary tasks such as edging green bricks, carrying bricks to the drying area, and assisting at the kiln. Among brickmakers in Russia, Sweden, and the United States that did not use inanimate power, larger firms employed substantially higher shares of women and children in all three countries as shown in Online Appendix Figure G2 and Table G1.

Although brick-moulding patents began to appear in the United States by the early 1850s, and steam-powered pug mills gradually replaced horse-driven ones, the diffusion of steam-powered machinery in brickmaking was slow and uneven through the end of the nineteenth century (Hounsell, 2022). Online Appendix Figure G1 shows that this pattern is visible in the census data. In Russia, Sweden, and the United States, brickmakers were more likely than other manufacturers to operate without inanimate power and less likely to use steam. Several forces kept the vast majority of brickyards reliant on hand methods: handmade bricks were considered superior in quality and commanded a higher price than machine-made bricks (United States Bureau of Labor, 1899), while the high fixed costs associated

with steam adoption may have further limited mechanization to the largest firms (Atack et al., 2008). The result was an industry in which the large non-mechanized brickyard—not the steam-powered factory—was the typical setting for the employment of women and children and where the expansion in scale rested on a greater division of labor and more developed supervision, not on fundamentally different production technology.

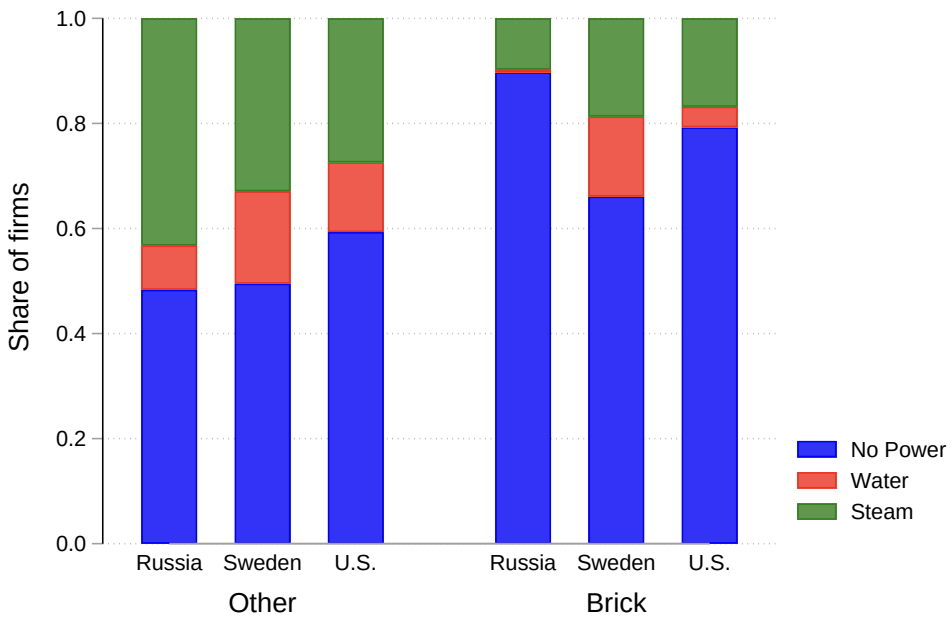
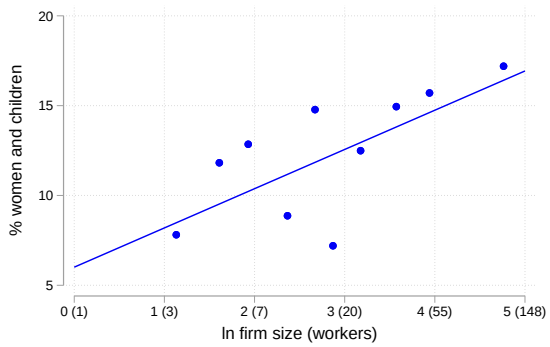
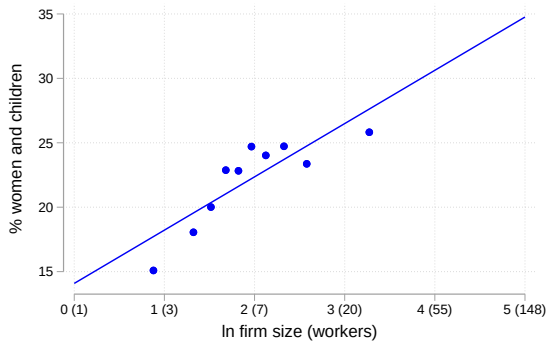


FIGURE G1: POWER USE AMONG BRICKMAKERS AND OTHER FIRMS

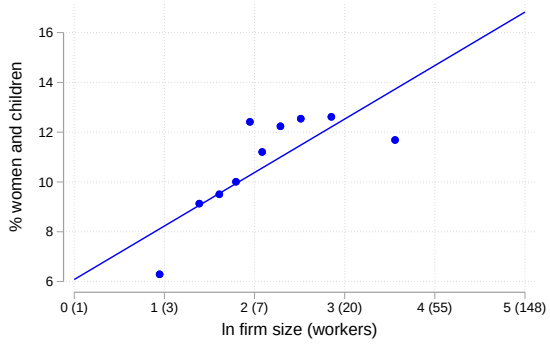
Notes: This figure displays the share of firms using no inanimate power, water power, and steam power among brickmakers and all other manufacturing firms in Russia, Sweden, and the United States. Each bar sums to one. The steam category includes firms using steam, with or without water power; the water category is limited to firms using water but not steam.



(A) Russia



(B) Sweden



(C) United States

Figure G2: Firm Size and Unskilled Labor: Brickmakers

Notes: This figure displays binned scatterplots of the percentage of women and children in total employment against ln firm size for brickmaking firms that use neither steam nor water power in Russia (Panel A), Sweden (Panel B), and the United States (Panel C). The Sweden and U.S. panels residualize the outcome and ln firm size using year fixed effects; the Russia panel is a single cross section. Each panel uses 10 bins; best-fit lines are estimated on the corresponding underlying data.

Table G1: Non-Powered Brickmakers

	Outcome: % women and children		
	Russia (1894)	Sweden (1864–1895)	U.S. (1870–1880)
	(1)	(2)	(3)
Firm size (ln)	4.982***	5.100***	0.945**
	(1.158)	(0.568)	(0.448)
Region × year FE	Yes	Yes	Yes
Mean outcome	11.82	22.45	10.48
Firms	565	3598	4840

Notes: Firm-level OLS regressions for brickmaking firms that use neither steam nor water power. The dependent variable is the percentage of women and children in total employment. The Russia specification includes region fixed effects; the Sweden and U.S. specifications include year × region fixed effects. Region corresponds to city/*uezd*, district (*fögderi*), and county for Russia, Sweden, and the United States, respectively. Robust standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

H Linking U.S. Firms

Linkage Process I link manufacturing firms observed in 1870 and 1880 using a conservative probabilistic matching procedure similar in spirit to that used in linking population censuses (Abramitzky et al., 2021). I first clean and standardize firm names by lowercasing the reported names, removing punctuation, expanding common abbreviations, and dropping legal suffixes and other generic firm-name terms. I then compare firms only within blocks defined by county, the 13-group linkage industry classification defined in Hornbeck et al. (2024), and the first letter of the standardized firm name. For each potential pair, I compute a bigram string similarity score based on the reported firm name following Wasi and Blasnik (2014), where I compare overlapping two-character sequences in the standardized names and measure the degree of overlap ranging from 0 (no shared bigrams) to 1 (identical strings). I convert this name score into a composite match score and retain the best-scoring 1880 candidate for each 1870 firm if the composite score is at least 0.95.

The linkage procedure is intentionally conservative and is sensitive to ownership changes that alter the recorded firm name, such as the addition of partners or other changes in ownership. As a result, the procedure may miss some true matches and therefore generate false negatives. But these restrictions also reduce the risk of false positives that would result from making a more liberal match on changing firm names. I view the tradeoff that I might match relatively fewer firms that underwent more substantial ownership changes and changed industries between 1870 and 1880 as appropriate given that I mainly want to track firms that change in terms of size and technology use, but that otherwise remain broadly similar in dimensions that might also affect the employment of women and children.

Linkage Rates Among the 113,718 U.S. firms observed in 1870 in the restricted analysis sample, 113,296 have usable firm names and are eligible to enter the linkage procedure. I link 13,744 of these firms to an 1880 record, or about 12.1 percent of the eligible sample. We lack reliable data on firm survival in the nineteenth century, which makes it challenging to benchmark this linkage rate. However, the BLS reports that the survival rate of manufacturing establishments today is less than 50 percent over a 10-year period, suggesting that I may link a relatively larger number of surviving firms (Bureau of Labor Statistics, U.S. Department of Labor, 2024). Note that the sample in the main analysis further restricts the sample to firms that have not adopted steam or water by 1870, which accounts for the smaller number of firms included in the main analysis.

Table H1: Selection into the Linked U.S. Panel

	All 1870	Eligible	Linked	Eligible, not linked	Difference (linked − not linked)	p-value
Firm size (ln)	1.524	1.524	1.856	1.478	0.377 (0.38 SD)	0.000
Any women or children (=1)	0.213	0.213	0.273	0.205	0.068 (0.17 SD)	0.000
% women and children	10.177	10.185	12.025	9.931	2.094 (0.09 SD)	0.000
Steam power (=1)	0.236	0.236	0.263	0.232	0.030 (0.07 SD)	0.000
Water power (=1)	0.164	0.164	0.186	0.161	0.024 (0.07 SD)	0.000
ln(HP per worker + 1)	0.586	0.585	0.607	0.583	0.024 (0.03 SD)	0.004
Urban (=1)	0.416	0.417	0.596	0.392	0.204 (0.41 SD)	0.000
Firm name length (characters)	13.687	13.728	14.026	13.686	0.340 (0.08 SD)	0.000
Food & beverages (=1)	0.162	0.162	0.148	0.164	-0.016 (-0.04 SD)	0.000
Textiles (=1)	0.179	0.179	0.187	0.178	0.009 (0.02 SD)	0.011
Leather (=1)	0.053	0.053	0.055	0.053	0.003 (0.01 SD)	0.170
Wood (=1)	0.254	0.254	0.243	0.256	-0.013 (-0.03 SD)	0.001
Paper & printing (=1)	0.024	0.024	0.032	0.022	0.010 (0.06 SD)	0.000
Glass, stone, etc. (=1)	0.052	0.053	0.063	0.051	0.012 (0.05 SD)	0.000
Chemicals (=1)	0.030	0.030	0.029	0.030	-0.001 (-0.01 SD)	0.356
Machinery & metals (=1)	0.245	0.245	0.243	0.246	-0.003 (-0.01 SD)	0.437
Firms	113718	113296	13744	99552		

Notes: This table compares firms observed in the 1870 Census of Manufactures that enter the linkage procedure to firms that are successfully linked to 1880. Columns 1–4 report means for all 1870 firms in the restricted analysis sample, firms with usable firm names after the cleaning and standardization steps used in the linkage procedure, firms linked to an 1880 record, and linkage-eligible firms that are not linked, respectively. Column 5 reports the difference between columns 3 and 4, with the difference expressed as a share of the eligible-sample standard deviation in parentheses. Column 6 reports the p-value from a test of equality of means between linked and eligible-but-not-linked firms. The 1870 sample contains 113,718 firms, of which 113,296 are linkage-eligible and 13,744 are linked to 1880, or 12.1 percent of the eligible sample. The firm-name-length row is based on firms with nonmissing reported firm names.

Evaluating the Linked Firms Table H1 compares the linked firms to the eligible firms that are not linked, showing that the linked firms are not a random subset of firms. Relative to firms that are not linked, linked firms are larger and more urban. The largest standardized differences are 0.41 standard deviations for urban location and 0.38 standard deviations for firm size. The estimate for firm size implies that linked firms are about 46 percent larger at baseline, while the 20.4 percentage point difference in urban location is about 52 percent of the mean among eligible firms that are not linked. Linked firms are also more likely to employ women or children, although the difference in the employment share of women and children is relatively small at 0.09 standard deviations. Differences in steam use, water use, and horsepower per worker are smaller in standardized terms. Industry composition is broadly similar across the two groups, with all standardized differences below 0.06 standard deviations.

Taken together, these patterns are consistent with the conservative firm name-based linkage that is more likely to recover firms that survive, remain in the same industry, and have stable ownership identity in 1870 and 1880. I further examine robustness to linkage quality in the main text.

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