Technological change and wage premiums amongst high-skilled labour: evidence from historical data

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Abstract

This study examines the impact of the steam engine, which produced wide and long-lasting economic growth from the 19th century to the early 20th century, on the wages of high-skilled seamen in the Swedish merchant maritime shipping industry. The analysis focuses on the years 1869-1914, which was a transition period during which traditional sailing ships were replaced by steam-powered vessels. The study shows that all high-skilled occupations received wage gains under steam technology. The evidence on wage polarization amongst the high-skill occupations remains subtle, although there is certain evidence that wage premiums vary by occupation.

Keywords: wage premium, technological change, high-skilled labour, historical data

JEL: J24, J31, O30

1. Introduction

Technological advantages are not only contemporary phenomena. The invention of the steam engine in the early 18th century affected almost all industries from the mid-18th to early 19th century and was one of the key driving forces behind the Industrial Revolution (Mokyr, 1992). Much like electricity in the early 20th century and information and communication technology (ICT) in the present day, the steam engine was a general-purpose technology, meaning that it allowed for more efficient relocation of economic activity and induced long-term growth (Aghion, Howitt & Violante, 2002).

The steam engine has had many applications across several industries. In shipping, particularly transoceanic shipping, the steam engine became useful, as ships were no longer at the mercy of favourable winds and currents. Consequently, the industry went through a technological change when sailing ships were gradually replaced by steam-powered vessels (Graham, 1956). The period also witnessed changes in employment and the wages of seamen (Chin, Juhn & Thompson, 2006; Ojala, Pehkonen & Eloranta, 2016).

This study examines the impact of the steam engine on wages in the context of historical data on Swedish sailors. The novelty of the study is twofold. First, it analyses wage premiums by occupation in a high-skilled labour group. Thus, the study contributes to the hypothesis of skill-biased technological change (SBTC) and polarization at the given skill level (Acemoglu and Autor, 2011). Second, the historical data provide an interesting and supplementary perspective to studies that have analysed data from the era of advances in ICT.

The study focuses on the period of 1869-1914, i.e., the transition years from sails to steam-powered vessels in the Western merchant marine and in the case of Swedish shipping (Fritz, 1980). We report OLS and FE estimates on wage changes that are associated with technological change. The results show that all high-skill occupations enjoy a wage premium on steam-powered vessels. The premiums do not vary amongst occupation, i.e., we find no support for the polarization hypothesis within the skill level.

2. Data considerations

The data consist of information on individual Swedish sailors from the Seamen's House documents. The Seamen's House was established in Sweden in 1748 to collect data on sailors for military use in the event of a war. The information includes names, ages, salaries, date of hire, occupation, and vessel characteristics such as type of ship,

technology, and size measured as tonnage, which allows the data to be formed into panel data and for the identification of individual sailors that reoccur in the data set.

The high-skill labour group is extracted from the original data[1]. The data consist of 16,091 observations (recruitments) with 9,592 different individuals from the period 1869-1914. Occupations that compose the high-skill group in the industry are constables (or 3rd mates), 2nd mates, 1st mates, steam engineers and captains. The occupations can be ranked by the skill level that they require. The least skilled sailors are constables and 2nd mates, while 1st mates and steam engineers have more experience and more formal training. Captains can be seen as the most skilled and the most experienced workers. Age provides indirect evidence of experience level. Constables (31.3 years) and 2nd mates (28.7 years) are, on average, the youngest skilled workers, slightly below the 1st mates (33.6 years) and well below the captains (43.1). Steam engineers are similar to 1st mates on steam-powered vessels with an average age of 34.3 years.

3. Steam premiums amongst high-skilled labour

The wage equation used to estimate the steam premium for high-skill labour is:

$$\ln W_{it} = \alpha_i + \beta_1 Steam_{it} + \delta \boldsymbol{Z}_{it} + \gamma_t + \varepsilon_{it} \qquad (1)$$

where i denotes the individual and t denotes time. The dependent variable is the log monthly wage in 1914 Swedish krona, deflated by using the consumer price index. The dummy variable $steam_{it}$ takes the value 1 when the individual is employed on a steam vessel. This coefficient measures the percentage difference in wages when employed on a steam ship compared to a sailing vessel. Vector $\boldsymbol{Z}_{it}$ includes controls for age, age squared, tonnage of the ship, duration of the contract, and occupation. α_i is the individual-specific fixed effect, γ_t denotes the year fixed effects, and ε_{it} is the random error term.[2]

The wage premiums are estimated by using three samples. The full sample consists of all seamen employed either on sailing vessels or on steam-powered vessels. The sample of switchers consists of those who switch from sailing to steam-powered vessels over the investigation period (or vice versa). Finally, we employ a subsample

[1] The total number of recruitments in the data is ca. 650 000. The number of individual sailors is smaller, as the same men could be recruited several times; see Ojala et al. (2016).

[2] Appendix 1 provides a glimpse of the data: share of steam vessels by tonnage from 1869 to 1914 (Fig 1) and wages of high-skill occupations for the early (1869-1889) and late period (1890-1914) of technological adaptation (Fig 2).

of switchers who retain their occupation by making that change. We use individual fixed effects to control for unobserved heterogeneity.

Table 1 reports estimates for the two sub-periods. The results show that the average wage premium declines over time. The estimate for the early period (1869-1889) is 29.6 per cent in the full sample and 23.5 per cent in the sample of switchers. For the later period (1890-1914), the estimates are 24.2 and 12.0 per cent. Although the precision and robustness of the analysis may suffer from sample size and an arbitrary cutoff point, the wage effects of technological transformation seem to diminish over the period. This finding is in line with occupational wage data; see Appendix 1.

Table 2 reports estimates for the whole period using alternative model specifications. In columns 1 and 2, we use the full sample of 16,091 observations. In columns 3-5, we use the samples of switchers. The uncontrolled steam premium is 68.2 per cent (column 1). The estimate decreases to 25.8 per cent when observable controls are included (column 2). In the sample of switchers, the estimate is 17.1 per cent (column 3). In the sample of switchers retaining the same occupation, the estimate is 21.2 per cent without individual-level fixed effects (column 4) and 16.7 per cent after applying fixed effects (column 5). In sum, the results show that the new steam technology creates a sizeable wage premium for high-skilled seamen, and that premium remains high after controlling for several confounders and unobserved individual heterogeneity. Furthermore, the comparison of the OLS and the FE estimates indicates that a considerable part of the wage premium can be associated with the individual characteristics of seamen.

Table 3 reports estimates by occupation.[3] The premiums are shown for captains, 1st mates, and 2nd mates with and without fixed effects; the number of observations for 3rd mates who switch technology is too low for empirical analysis. The results show that all occupations gain a wage premium. The estimate for captains is 19.5 per cent (column 1) and 12.4 per cent after fixed effects (column 2). For 1st mates, the estimate is 16.2 per cent (column 3) and 14.5 per cent with fixed effects (column 4). The decline in the premium amongst the captains suggests that the most skilled captains were selected to steam-powered vessels. For 2nd mates, the result is the opposite: less skilled 2nd mates move to steam vessels with the premium being 3.4 per cent without fixed effects (column 5) and 18.5 per cent after the controls (column 6). In sum, all high-skill occupations receive a wage premium, with estimates varying between 12.4 - 18.5 per cent.

[3] Due to the small size of the sample, we do not estimate specifications for switchers by occupations and separate periods.

4. Conclusions

The results show that high-skilled seamen on steam-powered vessels received an approximately 25 per cent wage premium compared to high-skilled seamen on sailing vessels and that the average wage premium declines over the adaptation period. The average premium decreases to 16 per cent after controlling for job change and unobservable individual characteristics. This implies that the most productive labour was more likely to move from sailing ships to steam-powered vessels. Overall, the findings are consistent with the hypothesis that the wages of workers performing abstract tasks increases as technology advances. The evidence on wage polarization amongst the high-skill occupations remains subtle, although there is some evidence that wage premiums vary by occupation.

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Table 1. Estimates of the steam premium for the early period (1869-1889) and the late period (1890-1914).

	(1) Full sample		(2) Switchers	
	Early	Late	Early	Late
Steam premium	0.296***	0.242***	0.235***	0.120***
	(0.014)	(0.012)	(0.035)	(0.031)
Controls	Yes	Yes	Yes	Yes
R2	0.812	0.794	0.891	0.810
N of obs	8019	8072	503	521
N of ind	4698	4894	190	200

Notes: Standard errors are clustered by individuals and reported in parentheses
** p < 0.1, *** p < 0.01

Table 2 Estimates of the steam premium; results for different samples, 1869-1914.

	(1) Full sample	(2) Full sample	(3) Only switchers	(4) Switchers same occ.	(5) Switchers same occ.
Steam premium	0.682***	0.258***	0.171***	0.212***	0.167***
	(0.011)	(0.009)	(0.025)	(0.031)	(0.032)
Controls	No	Yes	Yes	Yes	Yes
Fixed effects	No	No	No	No	Yes
R2	0.312	0.830	0.859	0.803	0.826
N of obs	16,091	16,091	1,024	643	643
N of ind	9,592	9,592	390	240	240

Notes: see Table 1.

Table 3. Estimates of steam premiums by occupation; technology switchers who retain their occupation, 1869-1914.

	(1) Captains	(2) Captains	(3) 1st mates	(4) 1st mates	(5) 2nd mates	(6) 2nd mates
Steam premium	0.195***	0.124***	0.162***	0.145***	0.034**	0.185***
	(0.047)	(0.060)	(0.023)	(0.029)	(0.054)	(0.066)
Controls	No	Yes	Yes	Yes	Yes	Yes
Fixed effect	No	Yes	No	Yes	No	Yes
R2	0.824	0.833	0.939	0.960	0.981	0.992
N of obs	235	235	291	291	105	105
N of ind	72	72	110	110	52	52

Notes: see Table 1.

Data Appendix

Figure 1: Share of steam vessels (%) by tonnage from 1869 to 1914.

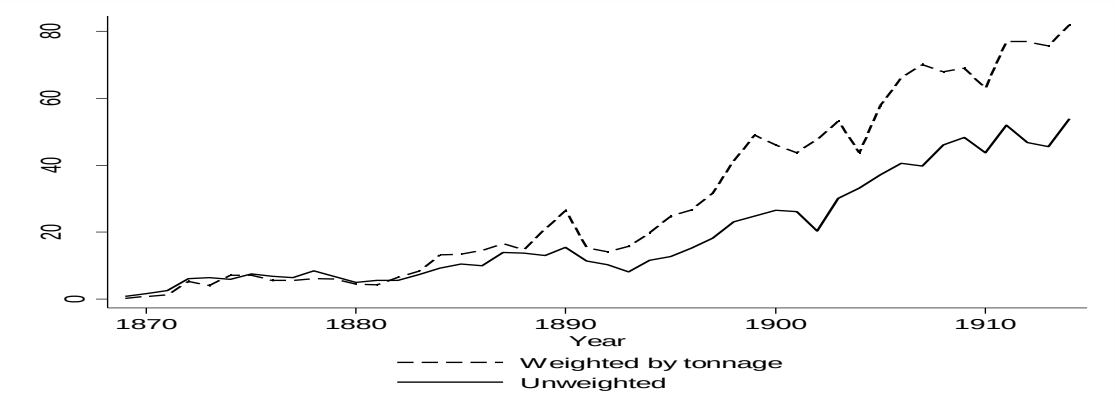

Figure 2: Average wages of high-skill occupations for the early and late period of technological adaptation.