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Technological change and wage premiums: Historical evidence from linked employer–employee data[☆]

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HIGHLIGHTS

• The steam technology had both new skill-demanding and skill-replacing aspects.
• High-skilled and unskilled labourers improved their relative wage positions.
• Findings are compatible with the hypothesis of technology-based polarisation.

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ABSTRACT

This study analyses the impacts of a technological change (the steam engine) on wage premiums. Using historical employer–employee panel data, we found that steam technology had both new skill-demanding and skill-replacing aspects. The former manifested itself as an increase in the demand for high-skilled engineers, the latter in a decline in the demand for intermediate-skilled, able-bodied seamen and an increase in the demand for unskilled engine room operators. Our panel data analysis, which controls for unobserved heterogeneity, implies that high-skilled labourers in abstract tasks and unskilled labourers in manual tasks improved their wage positions relative to intermediate-skilled labourers in routine tasks. These findings are compatible with the hypothesis of technology-based polarisation.

1. Introduction

The observed rise in overall wage inequality, particularly in the US and UK labour markets, has generally been accounted for by skill-biassed technological change (SBTC). According to the SBTC hypothesis, technological advances raise the relative demand for skilled labour, and thus skilled labourers' wages, in every task. The majority of studies have used empirical data from the last two or three decades, which has been a rational approach as the information technology (ICT) revolution[1] of the 1980s provided an interesting basis for research on the impact of new technology on the labour market. Bound and Johnson (1992), Katz and Murphy (1992), Berman et al. (1998), Juhn (1999) and Acemoglu (2002) have made well-known contributions in the area of SBTC. Katz and Autor (1999) offer an excellent review of the literature of the 1980s and 1990s, whereas Card and DiNardo (2002) and Lemieux (2006) provide a critical view of the helpfulness of the SBTC hypothesis in understanding shifts in the wage structure observed over recent decades.

The most recent literature has opted for a new concept: technology-based polarisation. According to this view, there has been a shift in

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[1] By ICT revolution, we refer to adoption of information and computer technology, such as the use of computer-aided manufacturing, digitisation, personal computers and related technologies, including the Internet.

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employment towards both the highest-skilled and lowest-skilled occupations with declining employment in the intermediate-skilled occupations. This view, also termed the "routinization hypothesis" (Autor et al., 2003), suggests that technological advances lead to an increase in the demand for jobs with non-routine tasks at the expense of jobs with routine tasks. Non-routine tasks can be either abstract jobs, such as managerial and professional positions, at the top end of the wage distribution, or manual jobs, such as services, at the bottom end of the wage distribution. Routine tasks, such as office jobs, are, in turn, concentrated in the middle of the wage distribution. Autor et al. (2006, 2008), Goos and Manning (2007), Goos et al. (2009), Van Reenen (2011) and Autor and Dorn (2012) are the most recent empirical contributors to this literature.

In this study, we contribute to the empirical research on the impact of technological change on the labour market by analysing historical data from an industry (shipping) that faced a significant technological change (the steam engine) in the mid-1800s.[2] Economic historians such as North (1958, 1968), Harley (1971, 1988), Fischer (1979), and Unger (2011) have all stressed the productivity growth caused by this technological change. Harley (1988) and North (1968), in particular, emphasise the technological change from sails to steam and from wood to iron and steel as the major source of this productivity growth and, thus, for the declining freight rates and, consequently, the increase in international trade.

The change in the quality and labour costs of mariners has attracted less attention, although the composition of crews changed as a consequence of the new technology. Chin et al. (2006) have noted that a premium was paid for the new groups of workers and to the seamen that had the same occupations on the steamers that they previously had on sailing ships. "Old" sailing professionals, such as able-bodied or ordinary seamen, could also be hired to work on steamers. New professions were also created, as there was a sudden need for high-skilled engineers and for unskilled workers, such as engine room operators, trimmers to carry coal and firemen to shovel the coal into the boilers. Furthermore, as noted by Kaukiainen (1991), with the advent of the steamship came the introduction of the passenger vessel, which led to the creation of more new jobs, such as stewards and waitresses.

This research uses Swedish merchant tonnage to study how the introduction of steam to merchant shipping affected the wages of the seamen. In Sweden, the first trial of a steam-powered vessel was conducted in 1816, but it would not be until 1899 that steam tonnage would surpass sailing tonnage.[3] Sweden's share of the world merchant fleet was between 2.5 and 3.0% during the latter part of the nineteenth century. As noted by Fritz (1980), in 1900, Sweden's share of the global merchant fleet was higher in sailing ships (3.5%) than in steam vessels (1.5%). The Swedish tonnage grew from the 1850s through 1870s, mainly through investments in new sailing vessels that peaked in the 1880s. From the early 1880s, the growth in Swedish tonnage was achieved through investments in steam vessels. While in 1880, the share of steam vessels was only 15% of total tonnage, by 1907 steam tonnage was twice as high as sailing tonnage. Thus, Sweden serves as a good case for the study of this technological change and its effect on the demand for skilled seamen.

The data used in this paper are compiled from the recruitment records of seamen's houses.[4] This Arkion database of Swedish merchant mariners consists of approximately 650,000 enrolments by seamen in various Swedish port towns. Our analysis utilises a sample from six towns spanning from the 1860s to the early 1910s. The data contain information on individual wages, job attributes and workplace characteristics. In particular, it provides information on mariners' occupations and includes a reference to job tasks. The dataset is outstanding and informative in two particular ways.

First, the technological innovation of the steam engine resulted in a major change in the maritime industry, that is, a gradual replacement of sail-only vessels by steam-powered vessels. The new steam technology not only changed the capital intensity of the industry but also created new occupations with new job tasks, including engineers and engine room operators, such as trimmers and firemen. The former group represents a high-skilled occupation focused on abstract tasks. The latter is a good example of an unskilled occupation focused on manual tasks. The transition period from sail to steam that lasted several decades provides an interesting and well-structured case to examine how the wages of old and new occupations evolve along with the adoption of a new technology. Analyses that exploit high-quality historical data to study wage structures are few, although they could offer perspectives relevant to the recent discussion on the impacts of technological change on the labour market based on data from the contemporary ICT revolution.[5]

Second, the dataset provides critical information for assessing the impact of a new technology on the wage structure. Two features of the data are particularly worth emphasising. First, we can relate occupations to job tasks, which, in turn, can be labelled abstract, routine or manual. This allows us to shed light on the emerging literature on technology-based polarisation that predicts an increase in the demand for skilled and unskilled labour in abstract and manual jobs at the expense of moderately skilled routine jobs. Second, panel data that draw a precise relationship between the seaman, the vessel and the prevailing technology, provide controls for observed and unobserved heterogeneity in the econometric analysis of wages. The ability to identify 1027 seamen who moved from a sail-only vessel to a steam-powered vessel or vice versa (adopters of the new technology) provides 3271 observations to estimate the wage impact of steam technology on different occupational groups during the period when the new technology was adopted.

The structure of the paper is as follows. Section 2 presents the theoretical basis of the study by discussing the role of production technology in the demand for skills in the context of the maritime industry. We combine Goldin and Katz's (1998) model of technology changes and demand for skills with that of Autor et al. (2003), who assume that technological change treats different job tasks non-monotonically, particularly by decreasing the demand for routine jobs. By describing the data in Section 3, we shed preliminary light on the hypotheses of skill-biassed technological change and technology-based polarisation in a historical context. The section describes changes that occurred in the maritime industry during the sample period, including the transition in the prevailing technology from sail-only vessels to steam vessels, changes in the occupational structure of the crews and basic statistics on wages by occupation and wage distributions by technologies and over time. The section also contributes to the literature by providing detailed information on workers who switch occupations due to technology (technology switchers): from which occupations and percentiles in the sail wage distribution the switchers to steam come and which occupations they obtained on steam ships.

In Section 4, we employ a regression framework and panel data methods to test the theoretical model derived in Section 2. The section consists of two parts. First, we analyse the direct wage effect of steam technology. This is performed by estimating the steam

[2] Although steam technology was first introduced in shipping around 1803, it was not until the late nineteenth century that the technology became efficient enough in long-distance trade to supplant sails, as noted in pivotal studies by Graham (1956) and Harley (1971).

[3] See Fritz (1980). The same was true for Denmark and Norway, which experienced the change from sails to steam around the-mid 1890s (Hornby and Nilsson, 1980; Gjolberg, 1980), while Finland did not make this transition until the first years of the 1920s (Kaukiainen, 1991).

[4] The data were compiled by Swedish National Archives in the late 1990s and published as a CD-Rom under the title "Arkion". For further information, see: http://www.arkion.ra.se/.

[5] Rare examples using historical data include Atack et al. (2004), Chin et al. (2006) and Goldin and Katz (2008).