TECHNOLOGICAL CHANGE AND THE LABOR MARKET: EVIDENCE ON THE IMPACT OF THE STEAM ENGINE IN LATE-19TH CENTURY MERCHANT MARITIME SHIPPING INDUSTRY

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JYVÄSKYLÄN YLIOPISTO

ABSTRACT

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Abstract

The rise in wage inequality in the late-20th century has been widely linked to technological progress and the non-monotonic effect it has on workers of different skill levels. Much of the work has been done in the context of recent advances in information and communication technology, which has revolutionized work since the 1970s. This Master's thesis provides information on the impact of the steam engine, which produced wide and long lasting economic growth from the 19th century to early-20th century. The analysis focuses on high-skilled seamen in the Swedish merchant maritime shipping industry from 1869 to 1914. During this time period steam-powered vessels gradually replace traditional sailing ships.

Five high-skill occupations are separately analyzed. Technological change from sail to steam caused large demand for new skills. The new occupation, steam engineers, enjoyed large real wages in the early period of technological adaptation. High relative wages of steam engineers are accompanied by large wage differentials within the high-skill group in the early adaptation period. Towards the end of the period the real wages of steam engineers grew slowly and declined, and the wage dispersion within the group declined. Overall, all occupations in the high-skill group received large absolute wage gains under steam technology. This premium prevails also after controlling for occupational change after switching from sail to steam and controlling for unobservable characteristics.

Keywords
skill-biased technological change, technological change, polarization

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Tiivistelmä Palkkaerojen viimeaikainen nousu kehittyneissä maissa on laajasti yhdistetty teknologiseen kehitykseen ja sen taitovinoutuneeseen luonteeseen. Suurin osa tutkimuksesta on keskittynyt informaatio- ja kommunikaatioteknologian kehitykseen viime vuosikymmenien aikana. Tässä tutkielmassa tutkin höyrykoneen vaikutuksia työmarkkinoihin 1800-luvun lopun merenkulussa. Tutkimuksessa käytetään hyväksi ruotsalaista tilastoaineistoa, josta tarkastellaan korkean taitotason merimiehiä vuosien 1869 ja 1914 välillä. Teknologinen muutos luo kysynnän uudelle korkean taitotason ammatille, konemestareille, jonka osuus höyrylaivoilla työskentelevistä korkean taitotason merimiehistä kasvaa lähes 40 prosenttiin vuoteen 1914 mennessä. Tarkastellun ajanjakson alkupuolella konemestareille maksettu palkka on korkea suhteessa muihin ammatteihin. Höyryteknologian yleistyessä konemestareiden palkkojen kehitys ei kuitenkaan yllä muiden ammattien tasolle, ja erot palkoissa tasoittuvat. Tarkastellessa teknologisen muutoksen vaikutusta kaikkien korkeasti koulutettujen merimiesten absoluuttisiin palkkoihin havaitaan höyryaluksilla työskentelyyn liittyvä huomattava palkkapreemio. Yksilöiden havaitsemattomista ominaisuuksista johtuvaa vaikutusta kontrolloidaan hyödyntämällä kiinteiden vaikutusten mallia, joka vahvistaa palkkapreemion olemassaolon kaikilla työntekijöillä. Nämä havainnot tukevat teknologisen kehityksen aiheuttaman polarisaation ennustamaa korkean taitotason työntekijöiden palkkatason kehitystä.	
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1 INTRODUCTION

Increasing wage inequality in the United States and other developed countries since the 1980s has been a widely discussed topic amongst economists in the late 20th century. A popular explanation for the rise in wage inequality is the non-monotonic effect that technological change has had on workers of different skill levels. The hypothesis of skill-biased technological change (SBTC) aims to explain these changes, suggesting that new technologies exhibit complementarities towards skilled workers thus increasing their productivity. More recently, several developed countries have moved towards wage and employment polarization. Routine-biased technological change (RBTC), aims to explain this observed polarization, which is seen as increased relative growth of employment and wages of top and bottom of the skill distribution at the expense of middle-skilled workers.

Changes in the labor structure related to technological change have been widely studied in the context of recent advances in information and communications technology (ICT). ICT has been a major driver of productivity growth in recent decades, and its effects stretch across all industries. It is not, however, historically unique in its influence on the global economy. The invention of the steam engine in the early-18th century massively affected all industries of advanced economies from the 18th to early-20th century and was to a large effect the driving force behind the Industrial Revolution. This Master's thesis aims to provide evidence on the impact of brought on by the steam engine in the context of the Swedish merchant maritime shipping industry. Introduction of the steam engine in the maritime shipping industry resulted in large changes to productivity and capital intensity. The shipping costs decreased as the steam engine allowed for the development of larger and more cost-efficient ships.

This Master's thesis utilizes individual worker data from the Swedish Seamen's House records. The original data, ranging from the 1750s to mid-20th century, is restricted to the time period between 1869 and 1914, which captures the transition period from sailing to steam-powered vessels. The analysis focuses on the high-skill sailors employed in five distinct occupations. Evidence of the effect of technological change on the occupational level within a skill group is not common, and the historical context of the data provided a unique view perspective to more recent changes seen in the labor market.

The rest of the work is organized as follows. Chapter 2 presents the theoretical background for analysis of labor market movements caused by technological change. Three distinct patterns are discussed: skill-biased technological change, deskilling and polarization. Chapter 3 reviews the previous literature surrounding technological change and the labor market, looking at evidence from the 19th and the 20th century separately. To provide an overview of the changes in wage and employment related to technological progress earlier research in Europe and the United States. As wealth of the research is done in the United States concerning the ICT, the review begins with wage and employment patterns seen during the 20th century.

Chapter 4 introduces the data and provides descriptive statistics of employment and wage movements seen in the industry among high-skill sailors. Finally, regression analysis is applied to estimate absolute wage changes associated with technological change. Fixed-effects estimator is used to control for individual and year specific unobservables. Chapter 5 concludes.

2 THEORETICAL BACKGROUND OF TECHNOLOGICAL CHANGE AND THE LABOR MARKET

2.1 Skill-biased technological change model

The hypothesis of skill-biased technological change (SBTC) started as an attempt to explain the rising wage inequality in developed countries in the latter part of the 20th century. In the basis of SBTC was the fact that in the 1980s the relative supply of high skilled workers was increasing, and this increase was accompanied by growing skill premium or the wage of high skilled workers relative to low skilled workers. SBTC suggests, that new technologies show complementarities towards skilled workers, increasing their productivity and demand. A supply and demand framework crafted by Katz and Murphy (1992) aimed to explain this simultaneous movements of relative supply and wage with a demand shift caused by skill-biased technological change. In this framework, technological change is biased towards high skilled workers, and new technological advances work as to increase the productivity of skilled workers and thus increase their demand. The following section will describe the framework following Acemoglu and Autor (2011).

2.1.1 The canonical model of SBTC

Consider two types of workers categorized by skill level to high-skilled workers and low-skilled workers. The skill level is linked to education or job training, with high-skill often proxied in literature by college education and low-skill indicated by high school education or less.

This model of SBTC coined as the canonical model by Acemoglu and Autor (2011) treats technological advances as naturally skill-biased and technical development as exogenous. Suppose a constant elasticity of substitution (CES) production function for the aggregate economy:

$$Y = \left[(A_L L)^{\frac{\sigma-1}{\sigma}} + (A_H H)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \qquad (1)$$

where $\sigma \in [0, \infty)$ represents the elasticity of substitution between high and low skilled labor, and A_L and A_H are factor-augmenting technology terms. The amount of low skilled labour that can be substituted with skilled labour is dependent on the size of elasticity of substitution, σ. If $\sigma > 1$, the H and L are gross substitutes, and when $\sigma < 1$, the H and L are gross complements. While the framework does not imply directly skill replacing technologies, increases in the technology terms A_L and A_H can either relatively complement or substitute workers depending on the size of the elasticity of substitution.

With competitive labor markets, the low skill and high skill unit wages are given by the values of marginal products, obtained by differentiating (1):

$$w_L = \frac{\partial Y}{\partial L} = (A_L)^{\frac{\sigma-1}{\sigma}}\left((A_L)^{\frac{\sigma-1}{\sigma}} + (A_H)^{\frac{\sigma-1}{\sigma}}\left({}^{H}\!/_{L}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \quad , \qquad (2)$$

for the low skilled workers, and

$$w_H = \frac{\partial Y}{\partial H} = (A_H)^{\frac{\sigma-1}{\sigma}}\left((A_H)^{\frac{\sigma-1}{\sigma}} + (A_L)^{\frac{\sigma-1}{\sigma}}\left({}^{H}\!/_{L}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma-1}} \quad , \qquad (3)$$

for the high skilled workers. To see how changes in the relative employment of workers affects wages, differentiate w_L and w_L by H/L: $\frac{\partial w_H}{\partial H/L} < 0$ and $\frac{\partial w_L}{\partial H/L} > 0$. This suggests that as the fraction of high skilled workers in the labor force increases, the low skill wage increases and when the fraction of low skilled workers in the labor force increases, the high skill wage increases.

Combining (2) and (3) gives the skill premium, high skill wage divided by the low skill wage:

$$\omega = \left(\frac{w_H}{w_L}\right) = \left(\frac{A_H}{A_L}\right)^{\frac{\sigma-1}{\sigma}}\left(\frac{H}{L}\right)^{-\frac{1}{\sigma}} \quad . \qquad (4)$$

By taking logs, function (4) takes form:

$$\ln \omega = \ln\left(\frac{w_H}{w_L}\right) = \frac{\sigma-1}{\sigma}\ln\left(\frac{A_H}{A_L}\right) - \frac{1}{\sigma}\ln\left(\frac{H}{L}\right). \qquad (5)$$

This shows the relationship between the skill premium relative supply of skills: for a given skill bias of technology A_H/A_L , an increase in the relative supply of high skilled workers causes the skill premium to decline when $\sigma > 1$. This can be seen by differentiating the skill premium equation (5) by the relative supply:

$$\frac{\partial \ln \omega}{\partial \ln H/L} = -\frac{1}{\sigma} < 0 \quad . \qquad (6)$$

This relationship contradicts with the simultaneous increase of skill premium and relative supply of skills observed in the U.S. during the 1980s (Katz & Murphy, 1992). Thus, it suggests that there has been a change in the skill bias of technology A_H/A_L. Differentiating the skill premium equation with respect to A_H/A_L gives:

$$\frac{\partial \ln \omega}{\partial \ln(A_H/A_L)} = \frac{\sigma-1}{\sigma}. \qquad (7)$$

Assuming $\sigma > 1$, a technological change favoring high skilled workers relative to low skilled workers increases the skill premium. According to Acemoglu (2002) the assumption of $\sigma > 1$ is reasonable for the United States from 1940 to 1990 (Acemoglu, 2002). Skill-biased technological change may also have a negative impact on the skill premium. Equation (7) shows that if the elasticity of substitution σ is less than 1, an increase in the A_H/A_L would cause the skill premium ω to decline.

Figure 1 Wage change by percentile 1963-2005 in the United States. Source: Autor, Katz & Kearney (2008)

Figure 1 shows the wage growth by percentile in the United States from 1963 to 2005 taken from Autor, Katz and Kearney (2008). The overall period shows monotonic growth of wage inequality, as the top of the distribution gains relative to the bottom. Given that the supply of high-skilled, or college educated workers has increased from 10 percent to over 30 percent between 1960 to 2005, the period must have seen large increases in the demand for skilled-workers as well. (Autor, Katz & Kearney, 2008.)

2.1.2 Deskilling

While the 20th century technological progress is mostly seen as skill-biased, evidence from the 18th and 19th century show signs of deskilling in the labor market. Deskilling is the increase in the share of unskilled workers employed or an increasing share of workers employed in low skill occupations, caused by a decline in the relative demand for skill. Technology based deskilling occurs when technological change allows for low skilled labor in combination with capital to perform tasks formerly done by more skilled workers. This was particularly the case during the industrial revolution in the 18th and 19th century, as large amounts of medium- to high-skilled workers were substituted by mechanization and unskilled labor (Atack, Bateman & Margo 2004; Katz & Margo, 2013).

Prior to the industrial revolution, manufacturing was mainly performed by skilled artisans in small artisanal shops. This method of manufacturing was labor intensive with completion of products often being done by single individuals from start to finish. With the invention of the steam engine, specialized machinery could be used in combination with low-skilled workers to perform the work earlier done by more skilled artisans in a large scale. (Katz & Margo, 2013)

Beaudry, Green and Sand (2016) provide more recent evidence on deskilling in the 21st century. They show that the demand for high-skilled workers has declined in the United States since the turn of the millennium. Relative employment of high-skilled workers has declined between 2000 and 2013, as the employment growth of college educated workers has slowed down. This phenomenon is explained by maturing of the IT-technology that has caused a decline in the growth of demand for high-skilled workers. Decline in the demand for high-skilled workers has caused skilled labor to move down to jobs traditionally occupied by less-skilled labor, pushing the low-skilled workers lower down the occupational ladder. (Beaudry, Green and Sand, 2016)

2.2 Routine-biased technological change

While the canonical model of SBTC can adequately answer the observed increase in wage inequality of the 1980s, the problem became more nuanced entering the 1990s. Technological change seemed to have different effects in the top, middle and bottom of the employment distribution. While the high-skilled workers at the top were receiving benefits from capital-skill complementarities, workers in the middle were suffering and declining employment. As the low-skilled workers at the bottom of the distribution were largely unaffected, this phenomenon is often referred to as job polarization. (Acemoglu & Autor, 2011)

Autor, Levy and Murnane (2003) extend the canonical model of SBTC to include the observed polarization of the U.S. labor market in the 1990s. They introduce a task framework in which technological change in the form of computerization affects the demand for skill used in different job tasks. The task-based model of technological change builds from the canonical model of SBTC but focuses on job tasks as opposed to skills. Workers of different skill level have a comparative advantage in different tasks. A task is a unit of work activity that produces output, and workers supply input to perform these tasks. The task-based approach means that skills are applied to tasks to produce output, while the skills do not directly produce output. The tasks are categorized as routine and nonroutine, which can then be divided into routine manual and abstract tasks and nonroutine manual and abstract tasks. (Autor, Levy & Murnane, 2003.)

Routine tasks are straightforward tasks that follow a set of rules and can be explicitly described with relative ease. The idea that technology substitutes for routine tasks is the major driver for routine-biased technological change hypothesis explanation towards employment polarization. These routine tasks are simple for machines to perform since performing the task always follows the same route. Routine abstract tasks include occupations such as bookkeeping and clerical work performed by middle-skilled workers. Routine manual tasks are seen in occupations such as repetitive manufacturing jobs and are often done by low-skilled workers. Nonroutine abstract tasks are seen in occupations that require flexibility and intuition, traits that cannot be accomplished by robotics and computerization. These occupations include managerial and specialist positions and are mostly performed by high-skilled workers. These jobs receive the largest complementarities from advances in information and communications technologies. At the bottom of the employment distribution are nonroutine manual tasks. These tasks require flexibility and are often service and janitorial jobs. Nonroutine manual tasks are hard for technology to substitute for and are often neutral to technological change. (Autor et al., 2003.)

Figure 2 Earnings growth by percentile in the United States. (Autor, Katz & Kearney, 2008)

The 20th and 21st century advances in ICT have been shown to especially exhibit polarization with complementarities towards nonroutine abstract tasks and substitution of routine manual tasks. Employment polarization can also be seen leading to wage polarization. Figure 2 shows the change in wage by percentile in the United States taken from Autor, Katz and Kearney (2008). From 1973 to 1988 the wage growth increases steady moving towards the top of the distribution. The later period 1988-2004, on the other hand, shows polarization of wages. Bottom of the distribution is gaining relative to the middle with largest increases in the top. In RBTC technological change is seen as exogenous decline in the price of computer capital which increases the relative demand for routine task input which can be seen as increase in computer capital or routine labor inputs. As routine and nonroutine tasks are productive complements, the relative wage paid to nonroutine tasks rises as the price of computer capital declines. (Autor et al., 2008.)

3 TECHNOLOGICAL CHANGE AND THE LABOR MARKET: EARLIER EMPIRICAL RESEARCH

Increasing wage inequality is a widely documented phenomenon in developed countries since the 1980s and is often associated with the increase in the skill premium. Skill premium is the ratio of wages earned by high-skilled workers relative to wages earned by low-skilled workers. For the United States, Goldin and Katz (2007) show that 65 percent of the growth in the overall wage inequality from 1980 to 2005 is explained by increasing skill premium, and according to Lemieux (2006), increased returns to post-secondary schooling explains 55 percent of rise in wage inequality from 1973 to 2005. As the skill premium increases, wage gains, experienced by the labor force, will be enjoyed by the high-skilled workers to a larger degree. As for the causes of rising skill premium, Burstein, Morales and Vogel (2015) are able to show that computerization can explain roughly 60% of the increased skill premium in the U.S. between 1984 and 2003 (Burstein, Morales & Vogel, 2015) and Autor, Katz and Krueger (1998) estimate that one-third of the increase in the employment of skilled workers from the 1970s to 1980s can be explained by the growth in investment in computers (Autor, Katz & Krueger, 1998).

3.1 20th to 21st century technological change

3.1.1 The United States

In the early 20th century the skill premium in the U.S. was considerably large. In fact, the wages of high-skilled workers relative to low-skilled workers did not reach its 1915 levels until the early-2000s. Between 1890 and 1910 the skill premium in the U.S. remained stationary (Goldin & Katz, 2009). Starting at 1910, the relative demand for high skilled workers started increasing, but was accompanied by a much larger increase in the relative supply of skills, which caused the skill premium to decline. The decline in skill premium continued up until the early 1950s, after which it increased sharply until the 1970s (Goldin & Katz, 2009). The overall wage inequality as measured by the 90-10 ratio decreased substantially during the 1940s. The 1950s and 1960s, on the other hand, saw very little changes in the wage inequality. (Goldin & Katz, 2007.)

Katz and Murphy (1992) look at changes in education premium between 1963 and 1987. During the whole period the relative wages of high skill workers increased substantially. A closer look shows, that while skill premium increased from 1963 to 1971, the period between 1971 and 1979 saw a clear decrease in the skill premium. This can be explained by a spurt in the growth of the supply of skilled workers in the 1970s (Acemoglu, 2002). However, from 1979 to 1987 the relative wages of skilled workers increased again with a period of slower growth in the supply of skills, leading to an increased skill premium for the overall period from 1963 to 1987. During this period, wage inequality started to increase greatly. 90-10 male log wage differential was stationary during the 1960s but started to increase in the 1970s. The 1980s saw a spurt in the growth of wage inequality, leading to an increase of 0.26 in the male 90-10 log wage differential for the overall period of 1963-1987 (Katz & Murphy, 1992.).

The growth of demand for skilled workers seems to have accelerated towards the end of the 20th century. Between 1970 and 1995 the growth of supply of skills was annually larger than between 1940 and 1970. Nevertheless, the skill premium increased rapidly during the latter period, while it, in fact, declined between 1940 and 1970. A closer look shows that after large increase in the relative supply of skilled workers in the 1970s, the growth of relative supply of skilled workers decreased in the 80s and the early 90s. This would indicate that the large increases in skill premium from 1980 to 1996 were as much caused by declining supply, as by increasing demand for skilled workers. (Autor, Katz & Krueger, 1998.)

Entering the 1990s, there seems to be a shift from skill-biased technological change to routine-biased technological change, or polarization. Between 1990 and 2000, employment growth of more skilled workers above the 75th percentile in the wage distribution grew rapidly, declined for the middle-skilled workers between 30th and 75th percentile, and increased slowly for the low-skilled workers below the 30th percentile. This employment polarization was accompanied by wage polarization as wage growth was relatively strongest below the 30th percentile and above the 80th percentile. After increasing sharply in the 1980s, the overall wage inequality grew slowly between 1990 and 2005. This was mainly caused by differing trends in the upper-tail and lower-tail wage inequality, measured by the 90-50 and 50-10 wage differentials respectively. While the upper-tail wage inequality continued to grow steadily, the lower-tail wage inequality stopped growing, or declined in the late 1980s. (Autor et al., 2008.)

Since the early 2000's, the growth in the high-skill premium seems to be slowing down. Valetta (2016) finds that between 2000 and 2015 the four-year college degree premium has not grown at all. For 2010-2015, the same is seen in all higher education wage premiums as the growth in wages becomes nonexistent (Valetta, 2016.). These recent changes in the skill premium could be caused by maturation of the information technology, as argued by Beaudry, Green and Sand (2013).

Table 1 Summary table of literature, United States in the 20th and 21st century.

Author(s)	**Data**	**Results**
Autor, Katz & Krueger (1998)	Census PUMS 1940-90, October CPS and MORG 1980-1996	Growing skill premium for high skilled workers for overall period of 1940-1996, with largest increases 1970-1996. Accelerating growth of demand for skilled workers.
Autor, Katz & Kearney (2008)	March CPS 1963-2005, May CPS 1973-78 and ORG CPS 1979-2005	Increasing upper-tail (90-50) wage inequality 1980-2005, stable wage inequality in lower-tail (50-10) after 1985.
Goldin & Katz (2007)	Census IPUMS 1940-60	Decreasing overall wage inequality (90-10) in the 1940s, stable overall wage in equality in the 1950s and 1960s.
Goldin & Katz (2009)	1890-1940 Administrative Records, Iowa State Census 1915-80, March CPS series 1915-40	1890-1940 skill premium, supply and demand. Declining education premium from 1915 to 1950s, followed by increasing education premium from 1950s to 1970s.
Katz & Murphy (1992)	March CPS 1963-1987	Skill premium increased from in 1960s (1963- 1971), declined in 1970s (1971-1979) and increased in 1980s (1979-1987). Wage inequality was stable in 1960s, increased in 1970s and 1980s.
Valletta (2016)	CPS MORG 1979-2015, March CPS 1979-2015	High education premium has not been rising between 1990-2015 the U.S.

3.1.2 Europe

Similar to the United States, the employment seems to be polarizing in several European countries in the late-20th century. Goos, Manning & Salomons (2014) look at the evolution of employment shares in 16 European countries between 1993 and 2010. They find that highest-paying and lowest-paying occupations have increased their employment share relative to middle-paying occupations in all 16 countries as a group, as well as in nearly all countries individually.

(Goos, Manning & Salomons, 2014.) Goos and Manning (2007) look specifically at changes in the labor market of the United Kingdom. Employment has polarized between 1979 and 1999. In the United Kingdom wage inequality has grown over the period, similar to the United States.

Focusing on the Nordic labor market, Asplund, Barth and Lundborg (2011) find signs of employment polarization. They look at the changes of the occupational wage distribution in Finland, Norway and Sweden in the decade following the year 1997. Employment polarization is seen in all countries, as employment growth is largest in the top and bottom of the wage distribution. The relative wages on the other hand have increased for the top-paying occupations but decreased for both middle- and low-paying occupations.

Table 2 Summary table of literature, Europe in the 20th and 21st century.

Author(s)	**Data**	**Results**
Asplund, Barth & Lundborg (2011)	Labour Force Survey (LFS) 1999, 2001 & 2005 for Finland, Wage Statistics 1997, 2000 & 2006 for Norway, Statistics Sweden 1997, 2001 & 2006 for Sweden	Employment polarization in the first half of 2000s, increasing relative wages for top, declining for middle and bottom.
Goos, Manning & Salomons (2014)	ELFS for 15 European countries 1993-2010, SIAB for Germany 1993-2008	Job polarization in most of the 16 European countries 1993-2010.
Goos & Manning (2007)	New Earnings Survey (NES) 1975-1999, LFS 1979-1999	Employment polarization and increasing wage inequality 1975-1999 in the United Kingdom

3.2 18th and 19th century manufacturing and sailing

While the 20th and 21st century economic evidence of technological change builds around the information and communications technology, the research of the 18th and 19th century focuses largely on the introduction of the steam engine. In the manufacturing industry, the utilization of steam technology meant a move away from labor intensive artisanal shops towards more capital-intensive means of production. Between 1850 and 1880 capital per workers increased by 75 to 95 percent in the U.S. manufacturing industry. Mechanization and capital deepening seem to have been connected to a larger percent of unskilled workers. (Katz & Margo, 2014)

Katz and Margo (2014) find that the use of steam power as well as the amount of capital in a manufacturing was associated with increased substitution of medium-skilled artisans by low-skilled workers between 1850 and 1910. During the period, the occupational distribution in the U.S. manufacturing industry hollowed out with increased share of high-skilled and low-skilled workers, and a decrease in the share of middle-skilled workers. This job polarization, however, does not occur in the aggregate economy during the period. Overall, the share of middle-skilled workers remained fairly stable, the share of high-skilled workers increased, and the share of low-skilled workers decreased mainly due to innovations in the agricultural industry. (Katz & Margo, 2014.)

In Swedish merchant shipping industry, the transition from sails to steam of the 19th century led to deskilling while also creating new demand for high-skilled workers as steam engineers, similar to manufacturing (Hynninen et al., 2013). The new technology allowed for the development of larger seafaring vessels, more low-skilled sailors were needed per one middle- or high-skilled seaman which lead to increased relative employment of low-skilled labor compared to middle- and high-skilled labor with an overall deskilling effect (Ojala et al., 2016). Chin, Juhn & Thompson (2006) find similar deskilling in North-American shipping, where the share of low-skilled seamen increased when moving from sail to steam.

Pehkonen (2014) finds that the growing sizes of steam vessels in Swedish merchant shipping was also associated with higher wages. The wage effect is especially prominent among high-skilled workers (Pehkonen, 2014). Looking at relative wages in the 19th century, Katz and Margo (2014) find evidence suggesting that increased relative employment for high-skilled workers was accompanied by increasing wages. They show growing skill premium over the period of 1820 to 1880, as measured by white collar workers wages relative to common laborer wages (Katz & Margo, 2014.).

In the U.S. manufacturing, wage inequality increased between 1850 and 1880. The 90-10 wage differential increased significantly over the period but most of the increase in inequality occurred below the median seen by the 50-10 wage differential. (Atack, Bateman & Margo, 2004.) Furthermore, Chin, Juhn and Thompson (2006) find that in North-American merchant shipping industry the introduction of steam was associated with larger wage inequality from 1891 to 1912. The overall inequality measured by 90-10 wage differential increased as steam ships gradually replaced sailing vessels. Large portion of this increase in inequality was the results of high wages seen among steam engineers, which was a new occupation created by technological change. (Chin, Juhn and Thompson, 2006.)

Table 3 Summary table of literature, United States and Europe in the 19th century.

United States		
Author(s)	**Data**	**Results**
Atack, Bateman & Margo (2004)	Atack-Bateman national manufacturing samples 1850-80	Increasing wage inequality between U.S. manufacturing plants
Chin, Juhn & Thompson (2006)	Maritime History Archive 1787-1936	More unskilled workers relative to skilled workers, deskilling. Greater wage inequality (90-10) in steam compared to sail.
Katz & Margo (2014)	Atack-Bateman national manufacturing samples 1850-80 for employment and establishment size, IPUMS 1850-1900 for employment	Relative demand for artisans decreased, demand for high-skilled workers increased
Europe		
Autor(s)	**Data**	**Results**
Ojala et al. (2016)	Seamen's House Data 1751-1913	Decline in skill premium, deskilling in sailing
Hynninen et al. (2013)	Seamen's House data 1869-1914	Increased demand for high-skilled and low-skilled seamen, technology-based polarization

4 DATA

4.1 Data considerations

The data[1] consists 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. Each observation marks the beginning of a sailor's contract, ranging from one to nine years. The information available for each observation includes names, ages, salary, date of hire, occupation, and vessel characteristics such as type of ship or technology and size measured as tonnage. This allows for the data to be formed as panel data and the identification of individual sailors[2] that reoccur in the data set.

Focusing on the top of the skill-distribution, occupations labeled as high-skill are separated from the original data, leading to 76,014 observations over the period of 1752-1942. The transition period from sailing to steam powered vessels extends from the mid-1800s to the early 20th century, with first steam vessel appearing 1854 in the data. To observe the effect of steam technology in the industry, the time period under focus is set from 1869 to 1914. This allows for analysis of an early technological adaptation period from 1869 to 1889, during which the share of sailors working on steam vessels grew from 1,5 percent to 17 percent. During the late period of technological adaptation, the share steam surpasses sail in 1905, with 68 percent of all sailors working on steam vessels by 1914.

Majority of the wage measurements are in Swedish krona, but include several other currencies as well annual and voyage-based contracts. Wages are deflated to 1915 Swedish krona and observations with other currencies, and missing information are left out, as well as wage outliers and obvious errors in

[1] See Ojala, Pehkonen and Eloranta (2016) for detailed information on the origins of the dataset.

[2] Variables under here to label individuals are: first name (initials), last name, year of birth, place of birth and place of residence.

coding. After removing missing information used to identify individual sailors, the data is compressed to 16,091 observations with 9,592 individuals. These observations are of occupations that make up the high-skill workers group of the industry: constables, 2nd mates, 1st mates, captains and steam engineers. By putting focus on the high-skill workers, it is possible to provide evidence on the effect of technological change at occupational level.

The five high-skill occupations can be roughly ranked by the skill level that they require. This allows for the analysis of employment and wage patterns within the skill group, and how they correspond with SBTC and routinization hypothesis. These theories of technological change predict most gains to be seen at the top of the skill and wage distribution, with less in the bottom and particularly the middle. The least skilled sailors could be expected to be working as constables (also referred to as 3rd mates) and 2nd mates, while 1st mates and steam engineers would have more experience and more formal training. Captains can be seen as the most skilled and the most experienced workers aboard shipping vessels. Table 5 provides some evidence on the experience levels of seamen in different occupations as measured by age. Constables and 2nd mates are on average the younger workers in sailing vessels, slightly below the 1st mates. As expected, captains are the most experienced workers under both sail and steam with an average age of over 40. Steam engineers are fairly similar to 1st mates by average age and would have been required to complete formal training. Only a few constables are seen on steam vessels and are therefore excluded from the comparison.

Table 4 Average age of high-skill occupations under sail and steam 1869-1914.

Occupation	**Average age**	
	Sail	**Steam**
Constables	31.3	-
2nd mates	28.7	32.8
1st mates	33.6	35.2
Captains	43.1	43.3
Steam engineers	-	34.4

4.1.1 Steam technology

Much like electricity in the early 20th century and ICT in present day, steam engine is a general-purpose technology meaning that it allows for more efficient relocation of economic activity and induces long-term growth ((Aghion, Howitt & Violante, 2002;Rosenberg & Trajtenberg, 2001). Invented in the early 18th century, the steam engine had many applications over several industries. In shipping, and particularly transoceanic shipping, the steam engine was especially effective, as ships were no longer at the mercy of favorable winds.

In the mid-1880s, technological improvements to the fuel efficiency of steam engines enabled steam vessels to become more cost-efficient compared to sailing vessels, which lead to an accelerated rate of technological transition (Chin et al., 2006). Early steam engines required vast amounts of coal to power, and this coal always took up space from the cargo itself. In 1860 steam vessels made up of 12 percent of the world merchant tonnage, and by 1910 nearly 80 percent of all merchant ships were powered by steam (Chin et al., 2006). The shipping costs of coal and grain, two of the largest trades of the period, decreased by 1.8 percent per year between 1870 and the early 1910s. This decrease in costs is heavily linked to the adaptation of steam powered machines in the vessels, as well as in ports. (Kaukiainen, 2006.) The use of industrial steam machinery in factories also decreased the cost of metal steam ships and further decreased the cost of shipping (Harley, 1988).

Technological change resulted in major changes in the crew composition aboard merchant ships as new occupations were created. Steam engines required engine room operatives, a low-skilled occupation tasked mainly with shoveling coal, and steam engineers, who were high-skilled workers educated in steam engine installation and maintenance. Engine room operatives and steam engineers together made up 45 percent of the crew aboard merchant steam vessels in North America (Chin et al., 2006) and 37 percent in Sweden (Hynninen et al., 2013). While these new occupations enjoyed a substantial wage premium compared to tradition occupations, a part of this can be seen as compensation for working in poor and dangerous conditions of the engine room (Chin et al., 2006).

4.2 Descriptive statistics

This sub-chapter aims to introduce the effects of technological change on the merchant shipping industry, as seen in the high-skill sailor data. Figure 3 shows the process of technological change seen as observations under sailing and steam-powered vessels. It plots the yearly observations from 1869 to 1914 under steam and sailing vessels separately. The early period shows very little usage of steam and slow adaptation of the new technology. During the late period the use of steam increases steadily while the share of sailing vessels declined causing steam observations to become more numerous by 1905.

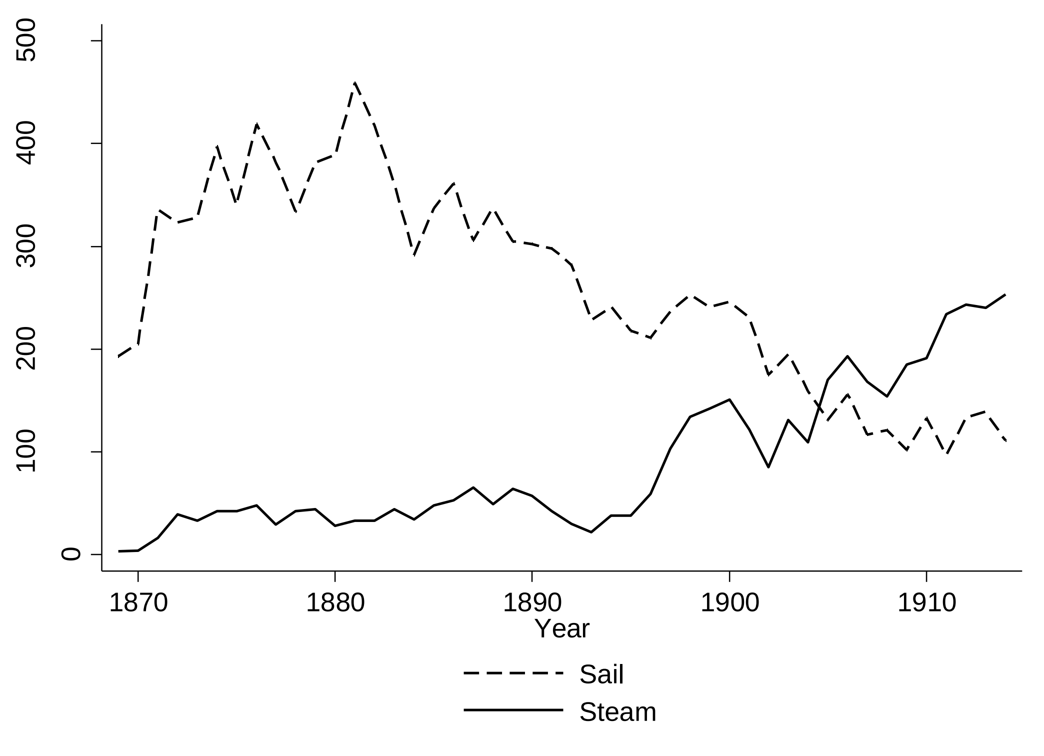

Figure 3 Yearly observations of high-skill sailors in sail and steam vessels, 1869-1914.

Figure 4 graphs unique vessels by technology and gives a more direct picture of the utilization of steam. Individual ships are identified[3] from the data and each ship is included only once each year. Unlike with sailors, the share of steam vessels does not pass sailing vessels until the early 1910s with seemingly slower growth. The lower relative number of steam vessels is explained by larger tonnages of steam powered ships. As noted by Katz and Margo (2014) the use of steam power was associated with growing factory sizes in manufacturing during the 19th century and a similar pattern is seen in the merchant maritime industry. Figure 5 shows the share of steam vessels unweighted and weighted by tonnage. During the late period, starting at 1889, the weighted share starts to grow ending at 83% by 1914 as compared to 52% of the unweighted share.

[3] Individual ships are grouped by name, ship type, and tonnage class.

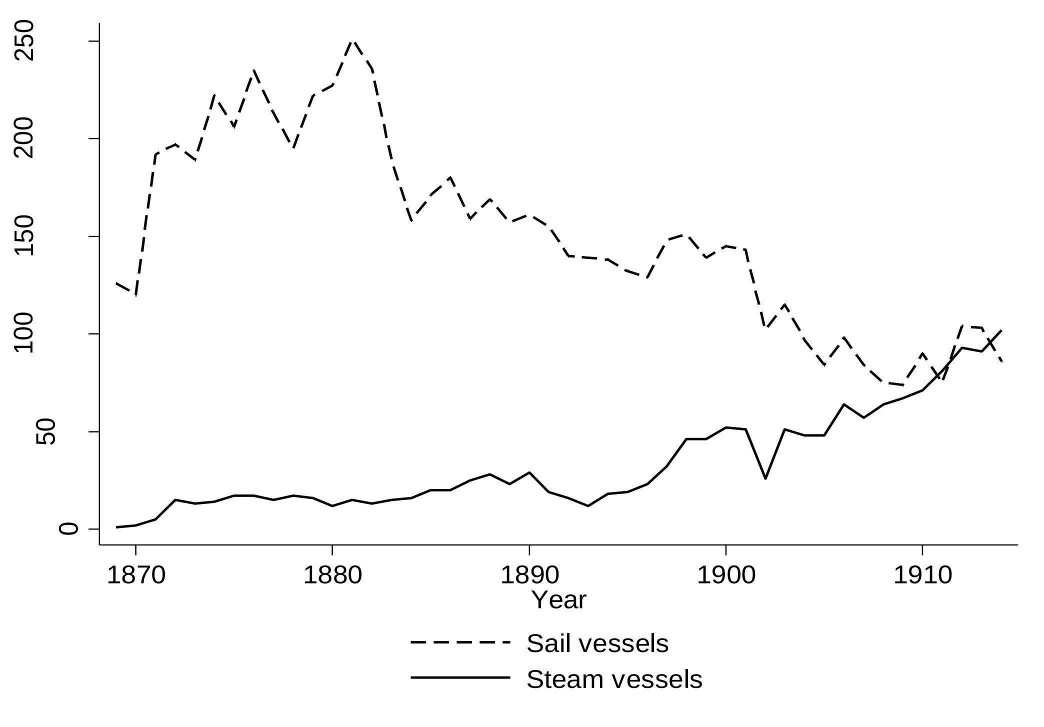

Figure 4 Technological change in the industry, yearly observations vessels from 1869 to 1914.

Figure 6 provides more evidence on growing sizes of ships using steam technology. The average tonnage of sailing vessels changes little or declines during the period. The size of steam vessels, on the other hand, increases substantially, with average tonnage three times as large as the sailing vessels by

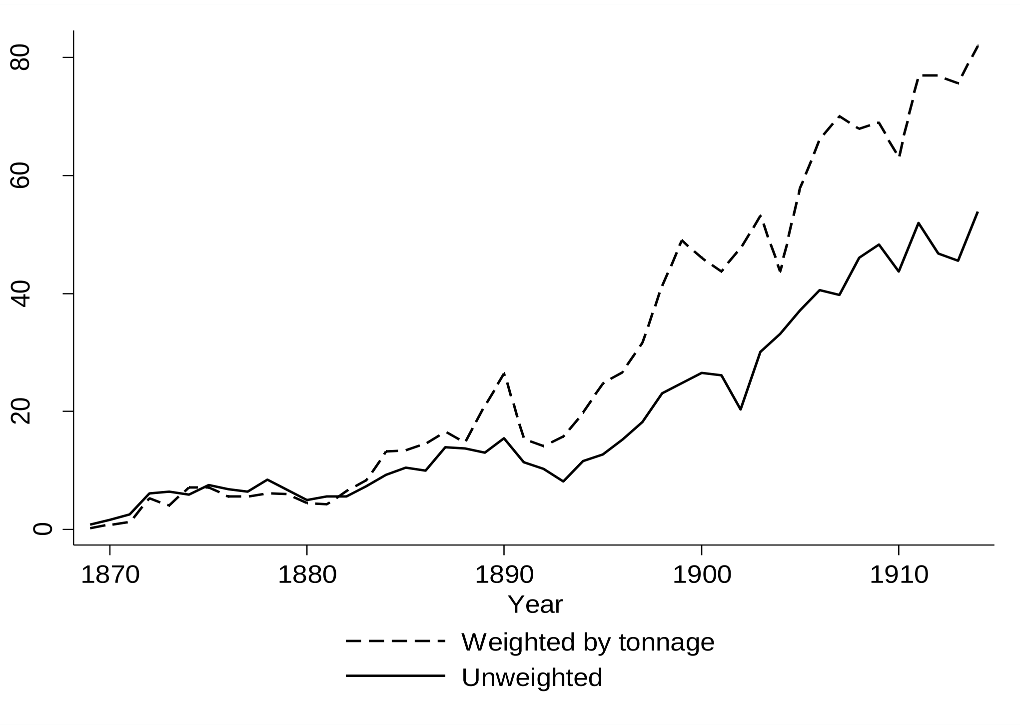

Figure 5 Share of steam vessels %, unweighted and weighted by tonnage from 1869 to 1914.

1914. Technological change seems to allow for better utilization of capital in form of ship tonnage. The capital to labor ratio seems to be shifting with the introduction of the steam engine as less sailors are needed to operate the level of tonnage as before.

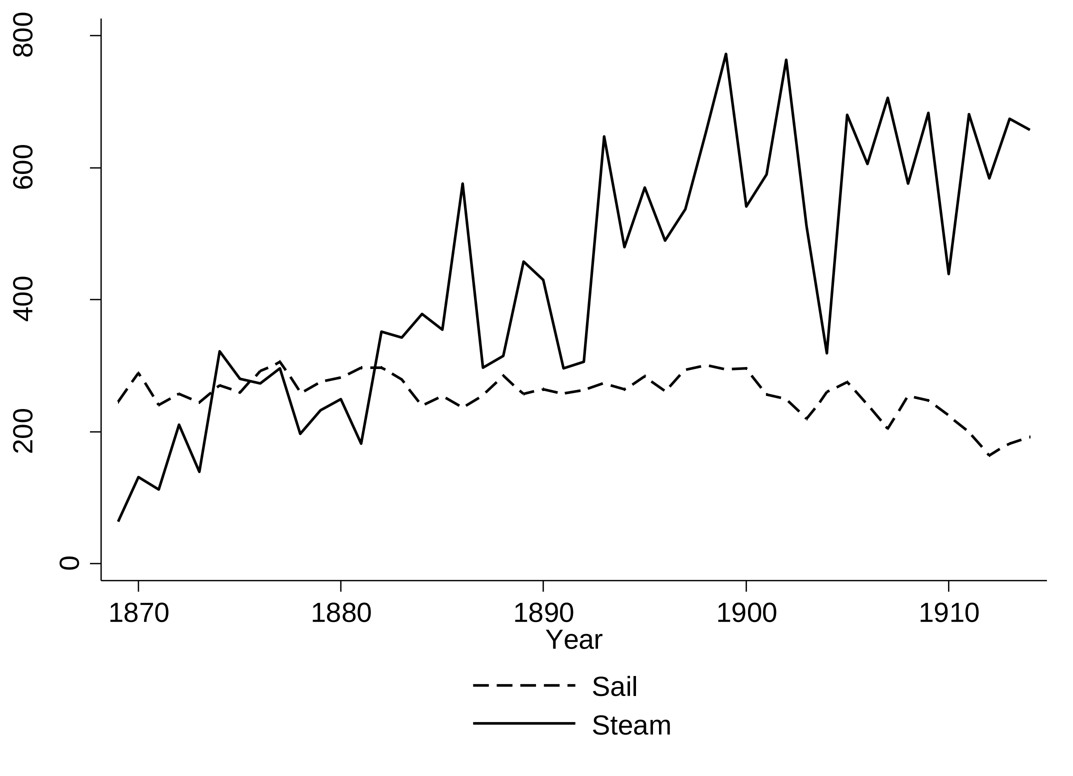

Figure 6 Average tonnage of steam and sailing vessels for high-skilled sailors, 1869-1914.

Figure 7 shows the changing employment structure among high-skilled seamen averaged for both technologies. The yearly employment share of each of the five occupations are calculated from 1869 to 1914. As expected, the share of steam engineers shows largest growth with nearly 20% employment share by the end of the period for the entire data. This is compensated by the declining employment of 1st mates by more than 20%.

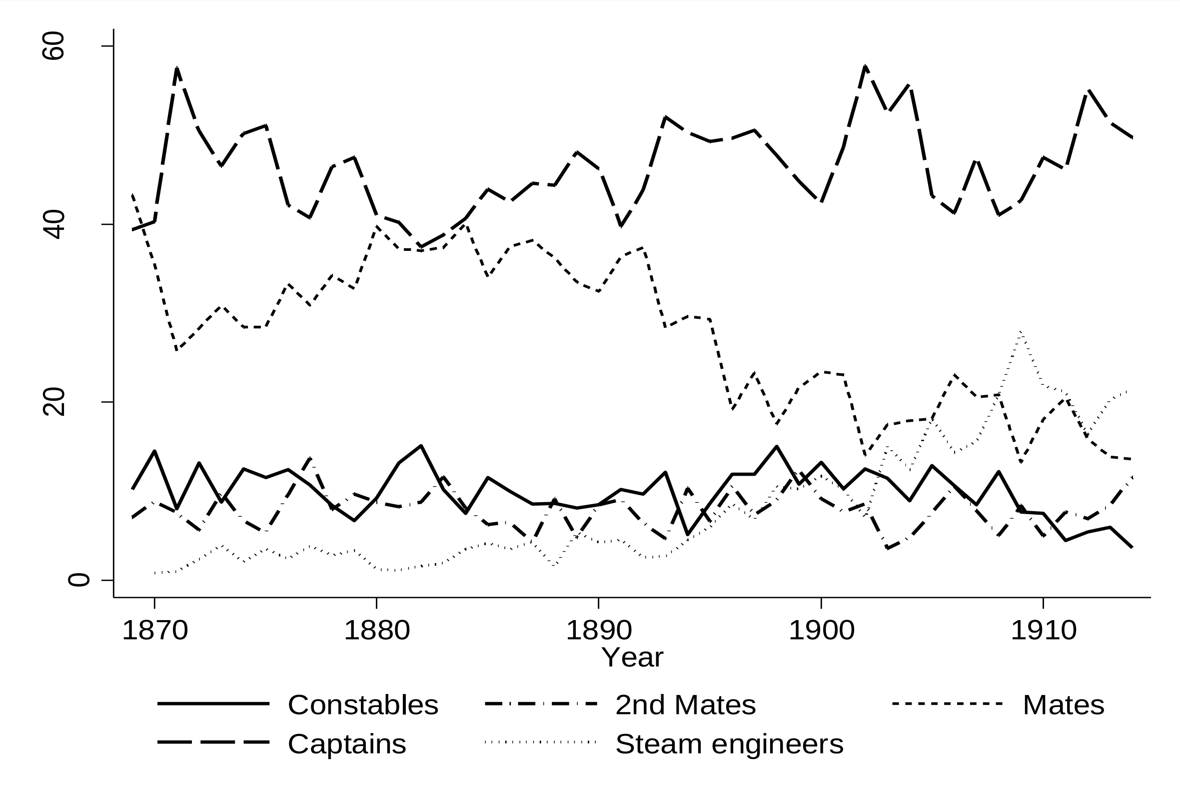

Figure 7 Evolution of the yearly employment share of high skilled seamen, 1869-1914

Table 5 quantifies the changes in occupational employment share, average tonnage, and the wage bill share. The employment share of constables is increasing share under sail technology, but practically nonexistent under steam technology. This might be caused by changes in job titles and descriptions unrelated to the technological change. It could also mean that the tasks previously performed by constables are performed by new occupations or machinery aboard steam vessels. On steam vessels, the share of steam engineers is nearly 40% during the late period and is met with a corresponding wage bill share. The difference in employment share of captains between sail and steam is more than 40% and likely reflects the growing size of steam vessels, as seen in panel C. The average tonnage of steam vessels grows to over two-fold of sailing vessels during the late period. Panel C also confirms the average tonnage trends seen in Figure 6. Average tonnages for each occupation are similar during the early period in sail and steam vessels. Average tonnages during the late period, on the other hand, remain same as in the early period for sail but increase by 70% to 100% for steam vessels. Average tonnages for occupations show some degree of variation. On average, captains are employed on the smallest ships under both steam and sail. This can be seen as a baseline for the average size of vessels. The two occupations that decline in employment and wage bill share, 1st mates and captains, are also employed on the smallest vessels by average tonnage.

Table 5 Employment share, wage bill share, and average tonnage, averaged over early period (1869-1889) and late period (1890-1914) for sail and steam separately.

	Sail technology			Steam technology		
	early	**late**	**difference**	**early**	**late**	**difference**
A. Employment share %						
Captain	39.5	50.8	+11.3	20.7	20.8	+0.1
1st Mate	37.7	26.6	-11.1	30.1	23.4	-7.3
2nd Mate	9.4	5.5	-3.9	12.4	16.9	+4.5
Constable	13.4	17.1	+3.7	2.1	0.5	-1.6
Steam engineer	n/a	n/a		34.7	38.4	+3.7
B. Wage bill share %						
Captain	38.1	49.2	+11.1	19.8	20.0	+0.2
1st Mate	39.3	28.0	-11.3	30.1	23.1	-7.0
2nd Mate	9.5	5.5	-4.0	11.7	16.8	+5.1
Constable	13.1	17.3	+3.6	2.1	0.5	-1.6
Steam engineer	n/a	n/a		36.6	39.7	+2.1
C. Average tonnage						
Captain	184	178	-6	283	500	+217
1st Mate	292	311	+19	268	523	+255
2nd Mate	461	479	+28	449	784	+335
Constable	325	331	+6	n/a	n/a	
Steam engineer	n/a	n/a		303	618	+315

Average log monthly wages for sail and steam technology are plotted in Figure 8. It shows the steam premium ranging between 55% and 70%, that is associated with steam vessels. The steam premium is largest during the early adaptation period of technological progress and decreases slightly over time.

Figure 9 looks at the evolution of average monthly wages for each occupation over both technologies. The graph of separated by early and late period of technological adaptation better for a distinction of wage trends. During the early period, the wages of steam engineers are substantially larger when compared to average wages of high-skilled seamen. This wage premium is most likely created by a combination of the steam premium and a low supply of skilled engineers in the early period. Steam engineers were required to undergo official education which included exams and apprenticeships, a process which took years and had an effect on the supply of steam engineers (Chin et al., 2006). During the early period, wages of other occupations show very little growth. In the late period as steam vessels become more common, average wages of all old occupations increase substantially. While the steam engineers still enjoy a wage

Figure 8 Average log monthly deflated wage of high-skilled sailors in sail and steam powered vessels, 1869-1914.

premium compared to other occupations, the growth in wages is lower leading to decreasing relative wages.

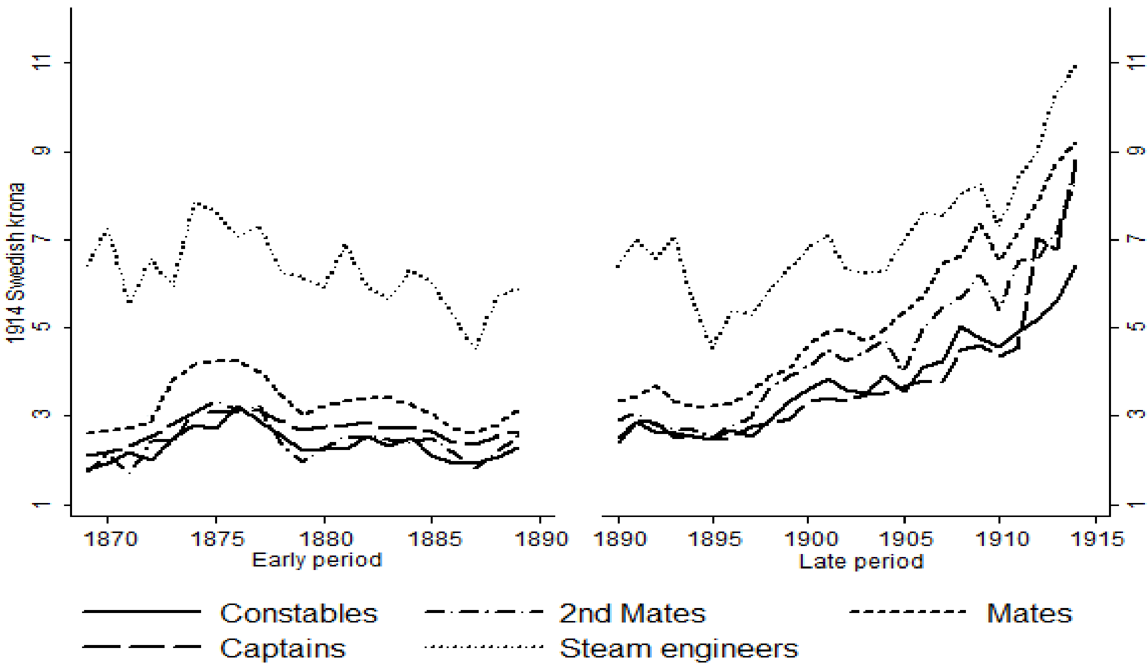

Figure 9 Average monthly deflated wages of high-skill occupations for early (1869-1889) and late period (1890-1914) of technological adaptation.

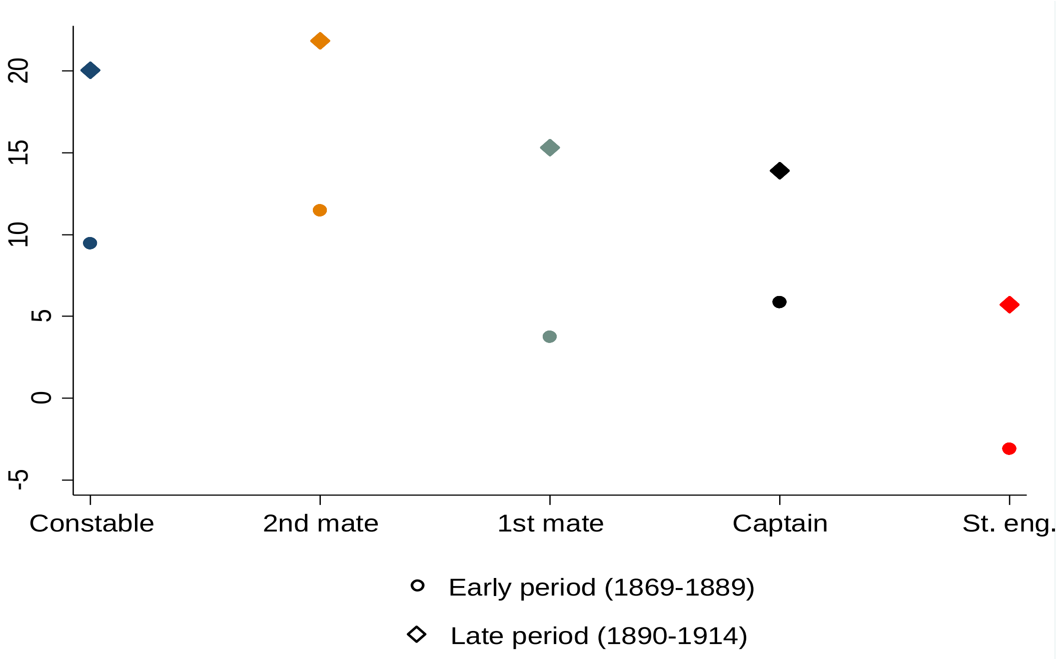

Figure 10 Average wage growth by occupation within the high-skill seamen for early (1869-1889) and late (1890-1914) periods.

Figure 10 confirms the trends seen in the growth of real wages. It shows the average growth of wages for each high-skill occupation for early and late periods. During the early period, growth of wages for steam engineers averages to below zero. This might reflect increasing availability of steam engineers, as the amount of steam vessels did not increase remarkably during the early period. Among the old occupations, wage growth seems to be largest for occupations requiring lowest skill levels, constables, and 2nd mates. Patterns for early and late period are similar, with largest average wage growth for least skilled and less so for the more skilled seamen. Wage growth of steam engineers differs from this pattern, having the lowest growth in wages for both periods.

Finally, Figure 11 and Figure 12 provide some inequality measurements. How have the changes in wages and employment, associated with technological change in the industry, affected the dispersion of wages among the high-skilled seamen? Figure 11 shows the log monthly wage ratio of workers in the 90th and 10th percentile of the earnings distribution, averaged for five-year periods from 1890 to 1910. Over the period the 90-10 wage ratio of high-skilled seamen drops from over 4 to less than 2. The majority of the decline in wage inequality is seen towards the end of the period as steam technology becomes more common in the industry.

Figure 12 shows inequality measurements for the two technologies separately. The pattern of wage inequality aboard sailing vessels is similar to the overall 90-10 wage differential with a sharp decrease in the early 20th century. On steam vessels, the 90-10 ratio starts low after which it increases for the middle part of the period. However, similarly to sail the wage dispersion declines

Figure 11 Difference in log average monthly wage of high skilled seamen at ninetieth and tenth percentiles, 5-year average, 1870-1910.

in the early 20th century. The decline in wage dispersion under steam is seen at the same time as decline is real wages of steam engineers around 1895 shown in Figure 9.

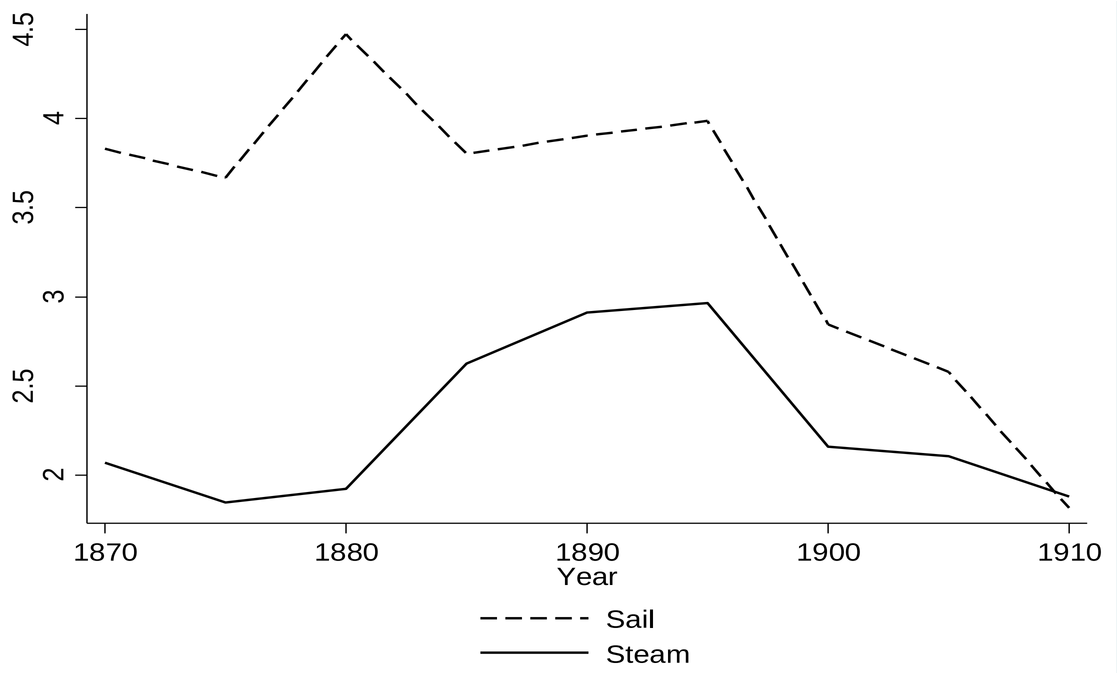

Figure 12 Difference in log average monthly wage of high skilled seamen at ninetieth and tenth percentiles for workers in sailing and steam-powered vessels separately, 5-year average, 1870-1910.

4.3 Empirical analysis on the steam premium

The following sub-section provides further evidence on the wage effects of technological change. Technological change could be expected increase wages of workers, which would be seen as a steam premium associated with steam-powered ships. The absolute steam premium is estimated for the full sample, as well as for sailors who switch from different technology to another, and those who retain their occupation while doing so. By looking at switchers in general it is possible to use individual fixed effects, while analysis of those who retain their occupation removes the effect of change in occupation when estimating the steam premium. Standard OLS estimates of the steam premium are complemented by using the two-way fixed effects estimator. By including individual fixed effects, it is possible to control for unobserved heterogeneity between the workers. Time fixed effects, on the other hand, most likely captures yearly fluctuation in the shipping industry.

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

$$\text{lnw}_{it} = \alpha_i + \beta_1 steam_{it} + \delta \boldsymbol{Z}_{it} + \lambda_t + \varepsilon_{it} \qquad (7)$$

where i denotes the individual and t denotes time. Dependent variable is the log monthly wage in 1914 Swedish krona deflated using the consumer price index. Dummy variable $steam_{it}$ takes the value 1 when the individual is employed on a steam vessel and is the primary concern of this analysis. The coefficient of this variable can be interpreted as a percentage difference in wages when employed on a steam ship as compared to sailing vessels. Vector $\boldsymbol{Z}_{it}$ includes control variables which are: age, age squared, tonnage of the ship, duration of the contract, occupation and year dummies. $\alpha_i$is the individual-specific fixed effect and λ_t denotes the year fixed effects and ε_{it} is the random error term.

Table 6 Aggregate steam premium for the high-skill seamen, full sample, technology switchers, and switchers who retain their occupation, 1869-1914.

	(1) Full sample	(2) Full sample	(3) Switchers only	(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
Number of observations	16091	16091	1024	643	643
Number of individuals	9592	9592	390	240	240

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

Columns 1 and 2 in Table 6 shows the OLS estimates of the steam premium for the full sample of 16091 observations. The premium for working on a steam-powered vessel for all workers is 68%, which is reduced to 25% after including the full set of controls. The steam premium for workers who switch between technologies, and those who remain in in their original occupation when changing technologies in two consecutive observations are reported in columns 3 to 5 of Table 6. For switchers in general the sample size is 1024 with 390 individuals and the steam premium is 17%. For switchers to the same occupations the sample size is reduced to 643 observations and 240 individuals, and the steam premium is 23% and 12% after applying fixed effects.

Table 7 Aggregate steam premium of high-skill seamen for the early period (1869-1889) and the late perid separately (1890-1914).

	(1) Full sample		(2) Full sample		(3) Switchers	
	Early	Late	Early	Late	Early	Late
Steam premium	0.586***	0.592***	0.296***	0.242***	0.235***	0.120***
	(0.016)	(0.013)	(0.014)	(0.012)	(0.035)	(0.031)
Controls	No	No	Yes	Yes	Yes	Yes
Fixed effects	No	No	No	No	No	No
R2	0.166	0.286	0.812	0.794	0.891	0.810
Number of observations	8019	8072	8019	8072	503	521
Number of individuals	4698	4894	4698	4894	190	200

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

For Table 7, the steam premium is estimated separately for the early (1869-1889) and the late (1890-1914) periods of technological adaptation. For the full sample without controls the steam premium is fairly even for both periods.

After including controls, the steam premium of the full sample is estimated to be 29% for the early period and 24% for the late period. Technology switchers show the same pattern, as the steam premium declines from 23% in the early period to 12% in the late period. Switchers who remain in their occupation are not included as the sample size is too small.

Next, the absolute steam premium is estimated for individual high-skill occupations. These observations are derived from the sample of seamen who remain in their occupation while switching technologies. Table 8 shows the estimated steam premium for captains, 1st mates and 2nd with and without fixed effects. The number of constables is too low on steam vessels for the estimation of steam premiums. All occupations show a substantial steam premium even after controlling for unobserved heterogeneity. For 2nd mates the steam premium is 3%, and 18% after including fixed effects. The steam premium for 1st mates is estimated at 16% and 14% with fixed effects, and for captains 19% and 12% after fixed effects. The 7% decline in the wage premium among captains suggests that generally more skilled captains were selected to work aboard steam-powered vessels.

Table 8 Steam premiums by occupation, evidence from technology switchers who retain their occupations, 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***
SE	(0.047)	(0.060)	(0.023)	(0.029)	(0.054)	(0.066)
FE	No	Yes	No	Yes	No	Yes
R2	0.824	0.833	0.939	0.960	0.981	0.992
N obs	235	235	291	291	105	105
N ind	72	72	110	110	52	52

Standard errors are clustered by individuals and reported in parentheses
All control variables are included in the estimates
** p < 0.1, *** p < 0.01

4.4 Discussion

The present chapter has provided evidence of the impact of technological change on high-skilled workers in the Swedish merchant shipping industry. Technological change is seen in the form of the steam engine which caused a transformation of the entire industry. Over the observed period, from 1869 to 1914, steam-powered vessels gradually replaced older sailing vessels with usage of steam surpassing sailing by 1905. Technological advances changed the capital intensity, as the size of steam-powered vessels were generally larger than sailing vessels. Occupational employment shares saw large changes, as steam technology created demand for a new high-skill occupation, the steam engineers. Changes in employment share were closely associated with wage bill share suggesting that the increasing supply was met with increasing demand. Employment share of steam engineers grew to nearly 40% towards the end of the period and was accompanied by similar wage bill shares. The occupation of constables made up of roughly 15% of the high-skill seamen in sailing vessels, but only a few percent under steam. Employment and wage bill shares of mates fluctuated also, as the share of 1st mates was smaller and the share of 2nd mates larger under steam technology. Overall, steam technology seems to have increased the demand for skills within the high-skill workers as the share of steam engineers, a relatively skill-demanding occupation, grew to nearly 40%.

Absolute wages on steam vessels were generally larger for all high-skill occupations. This is consistent with the polarization hypothesis which suggests that absolute wages of high-skilled workers performing abstract tasks increase as technology advances (Acemoglu & Autor, 2011). During the early period of technological adaptation, steam engineers enjoyed especially large real wages. Large wages of steam engineers could be in part explained by the nature of the shipping industry. Industries utilizing steam power on land might not have to employ steam engineers as regular workers, and only pay for engineers when machines needed installing or maintenance. Ships, on the other hand, would be forced to employ steam engineers for the duration of the voyage (Chin, Juhn & Thompson, 2006.). As technological adaptation continues, real wages of other occupations start to converge with those of steam engineers. Indeed, the average growth rates of individual occupations vary greatly, with negative wage growth for steam engineers over the early period. Within the high-skill workers, the largest wage growth is seen in the lower-end of the skill distribution with 2nd mates enjoying largest rates of wage growth.

The existence of a wage premium associated with the technological advances is further explored using regression analysis. Workers on steam vessels are estimated to receive a 25% steam premium compared to workers on sailing vessels, after controlling for available observable variables. Wage premium of 16% remains even after controlling for job change and unobservable individual characteristics, suggesting that the steam premium was not only limited to the most skilled sailors. Occupational steam premiums are also estimated for captains, 1st mates, and 2nd mates. Some variation exists across occupations, with largest steam premium seen for the 2nd mates, but these estimates could be skewed by the low sample sizes. Additionally, captains were often rewarded 3% to 5% of the shipment income as extra payment, which often exceeded their fixed monthly wage, and these payments are not included in the data (Kaukiainen, 2007). There is a possibility that some steam vessels were more productive than others and that the steam premium was only seen on these ships. This could be controlled for by applying additional ship fixed effects, as the data allows for the identification of individual ships, but this is not possible for the high-skill worker sample due to limited amount of observations.

Development of the wage dispersion within the high-skill seamen is also considered, using the 90-10 wage differential. The wage ratio of seamen in the 10th and 90th percentile of the wage distribution declines by nearly 50% from

1879 to 1910. This is most likely the result of large initial wages of the steam engineers, when the supply was scarce, followed by negative of slow wage growth of steam engineers and large positive wage growth of other occupations. These measurements, however, could be biased because of incomplete wage information on captains discussed above.

5 CONCLUSION

Using data of high-skill sailors from late-19th and early-20th century merchant maritime industry, this Master's thesis provided evidence on the impact of technological change on the labor market. Between 1869 and 1914, the maritime shipping industry went through a revolutionary period of technological change. Over the period traditional sailing ships were gradually replaced by steam-powered vessels, and this change was associated with changing patterns of employment and wages of the high-skill seamen. Technological change was associated with growing capital intensity as steam-powered vessels were on average larger than sailing ships. The growing usage of capital relative to labor is similarly associated with technological change in the late-20th century in the form of information and communications technology (Autor, 2014).

Technological change and the introduction of steam engines created a large demand for new skills that were needed to maintain the steam engines and created a new occupation, the steam engineer. The employment structure of high-skilled seamen was greatly altered, as the employment share of steam engineers grew to almost 40% of all high-skilled on steam vessels by early-1910s. The new occupation received large real wages during the early period, possibly caused by low supply of the steam engineers. Large real wages of the early period were also accompanied by large wage differentials within the high skilled group. Over the period, however, the wage growth of steam engineers was low or even negative, while the wages of other occupations increased. This resulted in a decline of steam engineer wages relative to other occupations and declining wage differentials.

A substantial wage premium was associated with working on steam-powered vessels. This increase in absolute wages is consistent with the polarization hypothesis. These wage gains are further confirmed by using fixed-effects estimation to control for individual time-invariant heterogeneity and year-specific fixed effects. Steam premium are also estimated for early and late periods of technological adaptation. As steam technology becomes more common, the steam premium seems to decline.

The evidence provided here show that the late-19th century Swedish merchant maritime industry went through a marked change with the introduction of the steam engine. Specifically, evidence of employment and wage changes of high-skill seamen are examined. The new skill-demanding aspect of steam technology as well as growing absolute wages of all occupations are discussed, among others. The primary findings suggest that the technological change had similar aspects to more recent technological innovations, namely, the ICT.

REFERENCES

Acemoglu, D., Autor D.H., 2011. Skills, Tasks and Technologies: Implications for Employment and Earnings. In Handbook of Labor Economics, Vol. 4, Part B. 1043-1171. Amsterdam: Elsevier.

Acemoglu, D.. 2002. Technical Change, Inequality and the Labor Market. Journal of Economic Literature, Vol. XL (March 2002), 7—72.

Acemoglu, D. & Autor, D.H., 2011. Skills, Tasks and Technologies: Implications for Employment and Earnings. Handbook of Labor Economics, 4(B), pp. 1043–1171.

Aghion, P., Howitt, P., Violante, G.L., 2002. General Purpose Technology and Wage Inequality. Journal of Economic Growth 7, 315-345.

Autor, D.H., 2014. Polanyi's Paradox and the Shape of Employment Growth, paper presented at the Federal Reserve Bank of Kansas City Jackson Hole Economic Policy Symposium, 21-23.08.2014.

Autor, D.H., Levy, F., Murnane, R.J., 2003. The Skill Content of Recent Technological Change: and Empirical Exploration. Quarterly Journal of Economics 118, 1279-1333

Autor, D.H., Katz, L.F., and Melissa S. Kearney. 2008. Trends in U.S. Wage Inequality: Revising the Revisionists. Review of Economics and Statistics (90), 300-23.

Autor, D.H., Katz, L.F., Krueger, A.B., 1998. Computing Inequality: Have Computers Changes the Labor Market? The Quarterly Journal of Economics 113 (4), 1169-1213.

Atack, J., Bateman, F., Margo, R.A., 2004. Skill intensity and rising wage dispersion in nineteenth-century American manufacturing. Journal of Economic History 64, 172–192.

Asplund, R., Barth, E., Lundborg, P., 2011. Polarization of the Nordic Labour Markets. Finnish Economic Papers 24 (2).

Beaudry, P., Green, D.A., Sand, B.M., 2016. The Great Reversal in the Demand for Skill and Cognitive Tasks. Journal of Labor Economics. Journal of Labor Economics 34 (1).

Burstein A., Morales, E., Vogel, J., 2015. Accounting for Changes in Between-Group Inequality. NBER Working Paper 20855.

Chin, A., Juhn, C., Thompson, P., 2006. Technical change and the demand for skills during the second industrial revolution: evidence from the merchant marine, 1865–1912. The Review of Economics and Statistics 88 (3), 572–578.

Goldin, C., Katz, L.F., 2009. The Race between Education and Technology: The Evolution of U.S. Educational Wage Differentials, 1890 to 2005. The Race between Education and Technology, Ch. 8. Harvard University Press.

Goldin, C., Katz, L.F., 2007. Long-Run Changes in the Wage Structure: Narrowing, Widening, Polarizing. Brookings Papers on Economic Activity, 2.

Goos, M., Manning, A., Salomons, A., 2014. Explaining Job polarization: routine-biased technological change and offshoring. American Economic Review 104, 2509–2526.

Harley, C.K., 1988. Ocean Freight Rates and Productivity, 1740- 1913: The Primacy of Mechanical Invention Reaffirmed. Department of Economics Research Reports, 8802. London, ON: Department of Economics, University of Western Ontario.

Hynninen, S., Ojala, J., Pehkonen, J., 2013. Technological change and wage premiums: historical evidence from linked employer–employee data. Labor Economics 24, 1–11.

Kaukiainen, Y., 2006. Journey Costs, Terminal Costs and Ocean Tramp Freights: How the Price of Distance Declined From the 1870s to 2000. International Journal of Maritime History 18 (2), 17-64.

Katz, L.F., Margo, R., 2013. Technical change and the relative demand for skilled labor: the United States in historical perspective. NBER Working Paper No. 18752.

Katz, L.F., Margo, R., 2014. Human Capital in History: The American Record.

Katz, L.F., Murphy, K.M., 1992. Changes in Relative Wages 1963-1987: Supply and Demand Factors. The Quarterly Journal of Economics 107 (1), 35-78

Rosenberg, N., Trajtenberg, M., 2001. A General Purpose Technology at Work: The Corliss Steam Engine in the Late 19th Century U.S.. NBER Working Paper 8485.

Ojala, J., Pehkonen, J., Eloranta, J., 2016. Deskilling and Decline in Skill Premium During the Age of Sail: Swedish and Finnish Seamen, 1751-1913. Explorations in Economic History 61, 85-94.

Valetta, G.V., 2016. Recent Flattening in the Higher Education Wage Premium: Polarization, Skill Downgrading, or Both? NBER Working Papers 22935.