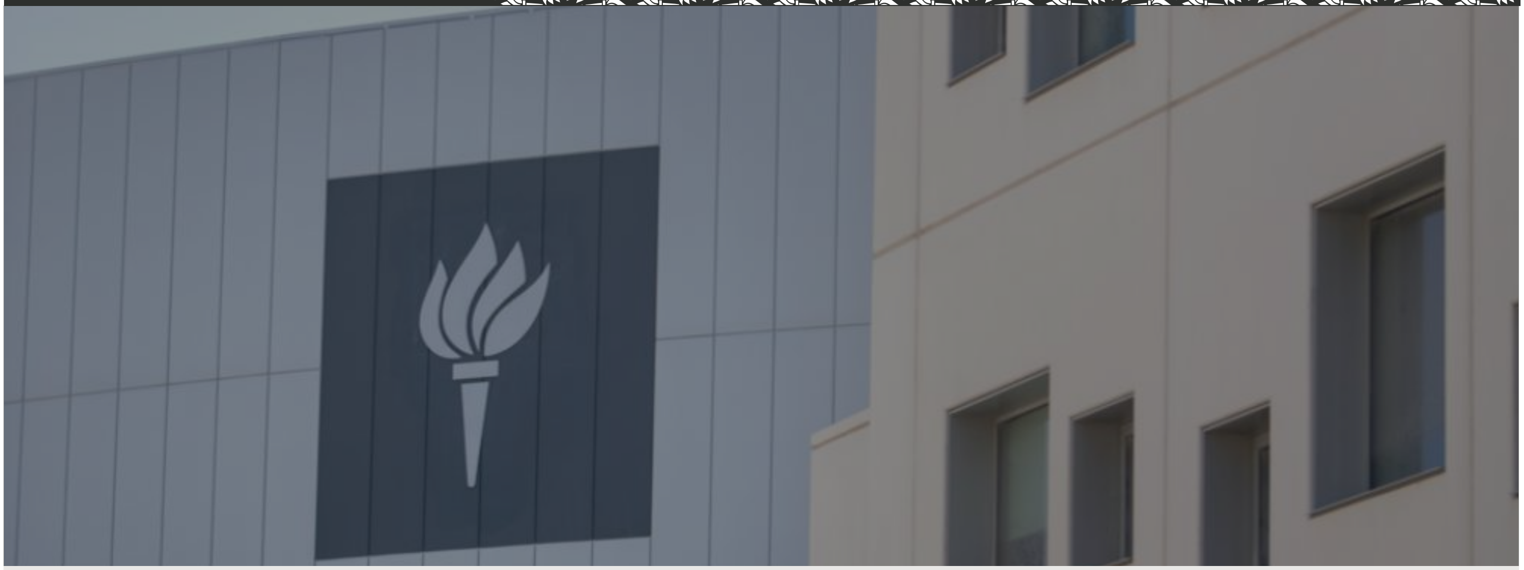
جامعة نيويورك أبوظبي
NYU | ABU DHABI



The Interplay among Wages, Technology, and Globalization: The Labour Market and Inequality, 1620-2020

Robert C. Allen

Working Paper # 0065
June 2021

Division of Social Science Working Paper Series
New York University Abu Dhabi, Saadiyat Island P.O Box 129188, Abu Dhabi, UAE
http://nyuad.nyu.edu/en/academics/academic-divisions/social-science.html

The Interplay among Wages, Technology, and Globalization: The Labour Market and Inequality, 1620-2020[1]

By

Robert C. Allen

Global Distinguished Professor of Economic History
Faculty of Social Science
New York University Abu Dhabi
Abu Dhabi, United Arab Emirates

Email: bob.allen@nyu.edu

2021

[1]I thank the following people for helpful comments and discussions: Alberto Bisin, Jonathan Chapman, Angus Deaton, Giovanni Federico, David Green, Jeff Jensen, Paul Johnson, Suresh Naidu, Patrick O'Brien, Jón Steinsson, and Peter Temin as well as the participants in seminars and workshops at New York University Abu Dhabi and New York, the Institute for Fiscal Studies, and the Centre for Economic Policy Research. A version of this appears as Allen (2021).

Abstract

For the past four centuries, technical change and the labour market have evolved together through a feed back process. Four phases in that history are distinguished here: the pre-industrial revolution (1620-1770), the industrial revolution (1770-1867), the age of industry (1867-1973), and the service revolution (1973-present). The focus is on the leading economy of each period–Great Britain in the first two and the USA in the last two. In all periods, output per worker has increased. In the first and the third, the average wage rose and wages tended to converge; in the second and fourth, the average wage was constant and wage and overall inequality increased. The feedback between wages and technology are discussed, and the causes of this periodization are explored. The roles of globalization and changes in the institutions responsible for technical change are discussed. The menu of policy choices to deal with the present labour market and inequality issues are considered in light of the history.

JEL codes: F16, F66, J31,J38,N62,N63,O33

keywords: technical change, labour market, induced invention,

For the last four centuries, technology and wage rates have evolved together. Over the long term, productivity has risen, and wages have increased. The interplay between technology and wages has not been smooth, however: Periods when growth was 'successful' with wages and productivity rising together have alternated with periods in which that synchronization has broken down, the average wage has fallen behind productivity, and the dispersion of wages among workers has increased. The first aim of this chapter is to block out these phase over the past four centuries. A second aim is then to explore how technology has affected the labour market, and how the labour market, in turn, has affected the evolution of technology.

Other factors, of course, have been involved in the evolution of technology and wages. The development of science has contributed to the development of technology both by discovering new knowledge of the natural world as well as by promoting the idea that the collection of facts and the development of theories can help us understand the world around us (Mokyr 1990, 2002, 2009, 2017). Globalization has also affected labour markets, although it needs to be recognized that globalization, in part, is the creation of technology. Finally, political and social institutions have influenced both technology and the labour market.

The history of the labour market bears on another issue of great importance– inequality. Piketty (2014), who has done much to advance our knowledge of the subject, has argued that inequality increases when the return on capital exceeds the growth in national income since the former (if re-invested) governs the growth in total capital and the income from it, while the latter equals the growth in incomes overall. But what determines the return on capital? When output per worker grows faster than the average wage, the share of profits in the economy rises and with it the return on capital. What is happening in the labour market, therefore, is a channel that affects the overall degree of inequality. Globalization also plays a role.[2]

Historically, the feed back between wages and technology has been a slow process, so it is best grasped by surveying a long time frame. I consider the last four centuries, and I divide them into four periods. The focus is always on the leading economy of the period. In the first two periods that is Britain, and in the last two it is the USA. In all periods, output per worker has risen, but they differ greatly in their distributional stories. The periods are as follows (all dates are approximate):

1. The pre-industrial revolution, 1620-1770.

Agricultural employment declined as a fraction of the British work force, and employment in urban and rural handicraft manufacturing expanded as exports of these goods surged to supply European and then imperial markets in the future USA, the Caribbean, and other possessions. Manufacturing still meant 'working by hand,' and the typical worker was a man or woman working in the family's cottage rather than in a centralized factory. By the end of the eighteenth century, labour markets were tight, and English wages were amongst the highest in the world. With output per worker and most wages rising, this was a successful outcome for the economy.

2. The Industrial Revolution, 1770-1867

High wages in Britain made it profitable to invent machines to save labour, and the result was the factory mode of production. The shift to factories meant that output per worker

---

[2]Critiques of Piketty and the endogeneity of his explanatory variables include Acemoglu and Robinson (2015) and Ray (2015).

in the economy increased. However, competition between the new factories and the established handicraft producers meant that some workers lost while others gained with the result that the average wage was flat while output per worker expanded and inequality rose.

3. The Age of Manufacturing, 1867-1973

Except for cyclical fluctuations, manufacturing output and employment expanded continuously, and real wages as well as output per worker increased. Rising real wages induced the invention of capital-intensive, high output technologies. Product innovation sustained the growth of manufacturing by creating new goods that kept consumers buying more and more manufactures. In addition, the USA had the West to settle, and Britain an empire to supply, and these seemingly limitless markets underpinned the expansion.

4. The Service Revolution, 1973-2020

Demand shifted away from manufactures towards services as technical change created more products dispensed through the service sector and more demand for its products. Output growth in manufacturing slackened. Growing imports of manufactures from newly developing countries, notably China, also made a contribution but one of secondary importance. High wages in the immediate post-war period created an incentive to substitute capital for labour, and the more recent fall in computer IT prices created further incentives in that direction. As a result, manufacturing employment has collapsed, and the service sector has expanded. Services offer many low wage jobs (as well as high salary jobs), so wage dispersion has increased. There has been only a negligible rise in the income of the average employee in the USA since 1973.

Capitalism worked well in the first and third periods in the sense that the incomes of the majority rose in step with overall labour productivity. In the second and fourth periods that synchronization came unstuck. Why? The common feature of periods two and four is that a new economic system was replacing the pre-existing one. In 1800 the factory replaced the cottage; in 2000 the hospital or restaurant replaced the factory. Schumpeter (1994, pp. 84, 87, 88) told us that capitalism progresses through a ‘perennial gale of creative destruction.’ Sometimes, that gale was exceptionally strong and blew away the existing structures destroying many livelihoods in the process. At other times, it was more like a gentle breeze, and most people prospered.

The framework of analysis

I approach these issues from a perspective on the dynamics of economic growth that emphasizes the same themes as endogenous growth theories. Two generations ago, Solow (1956) formulated his growth model that was hegemonic in economics and economic history for many years. In important respects, however, it is not consistent with the facts of the last four centuries, and it fails to address key features of capitalist development so a different approach is needed. Anything less than an endogenous growth model is useless. In this chapter I follow a path blazed by Romer (1986, 1990), Lucas (1988), Grossman and Helpman (1991) and Aghion and Howitt (1992). My approach to technical change, which is a key part of the story, follows Acemoglu (2002) and Acemoglu and Restrepo’s (2018, 2019) recent work. The following are some important features:

1. Production function.

The Solow model posits a neoclassical production function in which GDP depends on the labour force and capital stock. Instead, we think of the available technology as a set of discrete input-output coefficients. These describe the actual ways in which production can take place. This approach is akin to Acemoglu and Restrepo's use of a task based model of production.

2. Technical change

The Solow model assumes labour augmenting technical change, in which case, output per worker and the real wage increase at the same rate. This is meant to model the 'stylized fact' that the two increase in tandem in historical data (Kaldor 1957). However, this 'fact' is a generalization of what happened between the middle of the nineteenth century and the 1970s–phase 3 in my schema. It does not describe the industrial revolution or the past fifty years. Something is wrong.

There are other difficulties. A prediction of the Solow model with labour augmenting technical change is that output per worker rises at the same rate at all capital-labour ratios. This has not occurred. Long run macro data show that output per worker has, indeed, risen at the high capital-labour ratios in rich countries. However, at low capital-labour ratios such as those found in poor countries today and in today's rich countries at the beginning of the nineteenth century, there has been no increase in output per worker for two centuries. In addition, the output-capital ratio has been declining over time, although the Solow model implies it should remain constant (Allen 2012).

Finally, on the theoretical plane, a neoclassical production function and any kind of factor augmenting technical change has the implication that the production function shifts inward at every capital-labour ratio, that is, at every value of the ratio of the wage to the price of capital. This set-up precludes finding that the factor price ratio guides the invention of new technology (Acemoglu and Restrepo 2018, 2019). Indeed, Solow treated the evolution of technology as exogenous.

Instead, of this representation of technical change, it is more useful to think of it as the invention of a technique with a new set of input-output coefficients. With this approach it is easy to see that factor prices affect the evolution of technology.

3. Wage evolution

Since the Solow model assumes a neoclassical production function, the relation between wages and output per worker can be analyzed with standard marginal productivity theory in an aggregate framework. Instead, we take a disaggregated and historically specific approach to wage determination. In the Industrial Revolution, for instance, there is competition between new factories and old fashioned handy craft producers. The late nineteenth century looks much more like Solow-in-action, but even then the impact of immigration of the labour market must be analyzed to understand the evolution of the American labour market.

Phase I: pre-industrial economic growth: 1620-1770

The pre-industrial revolution ran from roughly 1620 to 1770, when the industrial revolution began. This is the period when sustained economic development began in Britain, and it was marked both by a 50% rise in output per worker (Broadberry, Campbell, Klein, Overton, van Leeuwen 2015) and a general increase in real wages. This was a marked break from the usual Malthusian pattern that characterized pre-industrial economies. In such economies, wages were normally at subsistence. Demographic shocks like plagues caused wages to rise, but they then gravitated back to subsistence. Across Europe real wages rose after the Black Death in the mid-fourteenth century, and in most places fell back to subsistence as populations rebounded. The major exceptions were the maritime cities on the North Sea like Antwerp, Amsterdam, and London. Real wages in London dropped slightly in the fifteenth century, but they quickly reverted to a high level and stayed there through the Industrial Revolution. In the rest of Britain, wages fell to subsistence, as they did elsewhere in Europe. By the seventeenth century, however, wages in Southern England began rising to the London level and by the eighteenth century this dynamism had spread to northern England (Figure 1). (Gilboy 1934, Allen 2001, Clark 2005, Humphries and Weisdorf 2019). Women's earnings rose relative to men's (Humphries and Weisdorf 2015). These trends meant that British real wages were amongst the highest in the world in the mid eighteenth century (Allen, Bassin. Ma, Moll-Murata, van Zanden 2011). These wage increases occurred at the same time that population was rising. The Malthusian pattern was broken (North and Thomas 1973, Clark 2007).

The wage patterns were a consequence of the shift of manufacturing from the Mediterranean to the North Sea that took place between 1500 and 1750. In 1500, at the end of the middle ages, Italy and Spain were the most urbanized countries and Europe's manufacturing power houses. The only comparably developed parts of north Europe were the Low Countries (modern day Belgium and the Netherlands). Otherwise, the continent was largely rural and agricultural. These differences in economic structure are illustrated in Table 1, which divides the population into three sectors–urban, agricultural, and rural non-agricultural. In 1500, the agricultural population made up three quarters of the total in England and the large continental countries. (This is the same proportion that one observed in less developed countries like India and China early in the twentieth century.) The percentage was lower in Italy, Spain, and the Low Countries. The latter had correspondingly larger urban populations, and that was important since most manufacturing took place in cities. The rural non-agricultural populations comprised a similar fraction of the population (14-19%) in all of the European countries in 1500 and consisted of servants in country houses, priests, workers in transportation, and village craftsmen satisfying local needs.

By the eve of the Industrial Revolution, the centre of manufacturing in Europe had shifted to the North Sea. The English economy was the most transformed. The agricultural share of the population had dropped to 45%, while the urban share jumped to 23%, and the rural non-agricultural share leaped to 32%–the highest percentage in Europe. London grew from 50 thousand people in 1500 to one million in 1800 when it became the largest city on the continent. Some of the growth in the urban share was due to an expansion in manufacturing (eg furniture making and book publishing in London, metal working in Birmingham and so forth), but much of it was due to the growth of commerce and shipping.

The growth of manufacturing was most apparent in the increase in the rural, nonagricultural share. In the seventeenth century, the wool and linen industries like many others expanded in the countryside. Merchants signed up men and women to spin yarn, weave fabrics, and knit stockings in their homes. The merchant brought the raw material to the workers, collected the finished articles, and paid the spinners and weavers for their effort. These rural industries were geographically concentrated, and their products were sold across Europe and, indeed, around the world. England was a leader in this so-called 'proto-industrial' revolution.

The Dutch and the Belgians were not far behind. Indeed, the Dutch economy was the most modern, if not the most transformed, by the end of the seventeenth century. The Netherlands was the most urbanized and had the smallest share of its population in agriculture. The great question in early modern political economy was how to catch up with the Dutch. Britain did it with the Industrial Revolution.

The other countries in Europe were transformed to a much lesser degree. There was a small decline in the agricultural share of the workforce in the big continental countries and a corresponding increase in rural manufacturing, but the cities remained small. These were not the economic leaders.

The economies of Spain and Italy were the least transformed of all. The stasis is somewhat deceptive–the constancy in the Spanish urban share encompasses the huge growth of Madrid and the collapse of the old manufacturing cities. Nonetheless, Italy and Spain had slipped from first to last place in European economic performance.

Why were the economies of England and the Low countries so radically transformed? The answer lies in the evolution of the international economy and the imperial and military policies of the governments of Europe. In the middle ages, pepper, cinnamon, nutmeg and other spices were exported from India and southeast Asia to Europe via the middle east. In the fifteenth century the invention of the square rigged ship allowed Europeans to sail around Africa to Asia. Vasco da Gama reached India in 1498, and his success led to the establishment of a Portuguese empire in Asia, Africa, and Brazil. Success was short lived, however, for many of the Asian colonies were seized by the Dutch in the sixteenth century. Some years before Vasco da Gama’s voyage, Christopher Columbus convinced King Ferdinand and Queen Isabella of Spain to fund his attempt to reach Asia by sailing west across the Atlantic, and he reached the Bahamas in 1492. The ‘discovery’ of America (the Grand Banks of Canada had been frequented by European fishermen for centuries) led to a scramble for colonies in which Spain looked the early winner, for the conquest of Mexico and Peru gave her vast quantities of silver. This treasure proved counterproductive for the economy, however, since it led to inflation that rendered Spanish agriculture and manufacturing uncompetitive (Dreilichman 2005). By the seventeenth century, England, France, and other powers were seizing colonies in the Caribbean, where fortunes were made in sugar plantations manned with African slaves. The English also established a string of colonies along the east coast of North America. These markets were large–by 1770, the colonies of the future USA had a population of 2.4 million, about one third of England’s. Incomes were as high or higher than in Britain (Allen, Murphy, Schneider 2012, Lindert and Williamson 2016), and most manufactures were imported. This was a big market for English goods. Bengal was conquered by the English East Indies Company in 1757. The Dutch and the French also founded colonies in India, the Carribean, and North America, but they were defeated by the English who took many of their colonies from them. The English and the French followed ‘mercantilist’ economic policies and used tariffs and other trade restrictions to secure their colonial markets for themselves. As the English empire expanded, so did the market for English manufactured goods, and this led to the great expansion of rural manufacturing and urban employment shown in Table 1.

The expansion in manufacturing employment had important knock-on effects. One was tight labour markets that led to high wages. Others included the agricultural revolution and the development of the British coal mining industry (Allen 2009). Cheap coal was an important reason that the metal working industries could compete internationally even though they paid higher wages than their competitors. High wages may have induced some labour saving technical change before 1770, but the big impact was after 1770 when the textile industry was mechanized.

Phase 2 Industrial Revolution, 1770-1867: wages affected technology

This period is the classic Industrial Revolution. It was driven by technological change. The Industrial Revolution saw momentous technological inventions like factory spinning, power loom weaving, a coal based iron industry, steamships, and railways. Invention in this period was focused mainly on cutting the cost of manufacturing existing products rather than creating new products. The textile inventions are emblematic, and they lowered the cost of producing yarn and cloth that were already being made by hand or that were very close substitutes for them. For a century, the steam engine's sole contribution to progress was to reduce the cost of pumping water out of mines (Crafts 2004).

Invention in this period was not conducted in research laboratories but was rather the work of individuals following their own ideas. They did not always operate alone, however. At the highest level, the Royal Society heard papers on atmospheric pressure and was alive to possibilities of using that force for power generation. More prosaically inventors met in local groups, shared ideas, and learned from each other (Mokyr 2009). It was not uncommon for inventors to share information so that they could learn from each others' experiences and push new design ideas forward. A good example of this sort of 'collective invention' was the perfection of Cornish pump engines in the first half of the nineteenth century. (Allen 1983, Nuvolari 2004). The aim of inventors was generally to find a device they could exploit themselves or sell or license to someone else who would do so.

The search for better devices was a sensible response to Britain's economic expansion between 1600 and 1770, for it created a unique wage and price environment that made the new machines of the Industrial Revolution profitable. British wages were high relative to the price of consumer goods, and, more to the point, relative to the price of capital services. (Figure 2 plots this ratio for northern England, France, Austria, and India).

The impact of the high wage on invention is clearer if we think about technical change as the invention of new techniques represented by single points in capital-labour space rather than as shifts in a standard production function. Figure 3 illustrates this point using spinning as an example. Two techniques are shown for spinning cotton yarn. The spinning wheel had a low capital-labour ratio, while the spinning jenny had a higher ratio. England in 1770 was characterized by the 'high wage cost line,' while the rest of the world (and England in 1600) had the 'low wage cost line.' Before 1770, the spinning wheel was the only technology available for making coarse cotton yarn, and it was used world wide, whatever the relative factor prices. In 1770, the spinning jenny was only profitable in England, so that was the only place it was used, and, indeed, the only place where it was worth inventing it.

Mechanical spinning was continuously improved from the 1760s into the nineteenth century. Hargreave's first machine was followed by Arkwright's water frame (plus associated machines to make the first cotton mill), Crompton's mule, Robert's self-acting mule, and so forth. This trajectory of improvements is indicated on the diagram. Point C represents Hargreaves' first attempt at making a jenny. It was too inefficient to be used commercially. The thick dotted line represents the improvements Hargreaves made during the R&D phase of the project that turned it into a commercially successful technology. The double dotted line to the 'tipping point' represents improvements to mechanical spinning after the jenny entered commercial service. At the 'tipping point,' machine spinning became profitable in low wage economies. That is when the industrial revolution jumped to the continent, and it did so through the adoption of the most advanced technology since that was the only technology that paid where labour was cheap. The double dotted line towards the origin indicates subsequent improvements.

The mechanization of spinning was followed by the invention of power loom weaving and similar incentives were in play. In the 1780s thousands of spinning jennies were installed in cottages and workshops and hundreds of Arkwright mills were constructed. Output of cheap cotton yarn surged. This yarn had to be woven into cloth, and the result was a large expansion in the handloom weaving sector. The weavers were mainly men. As the sector expanded, weavers' wages, which had been similar to those of building labourers and farm workers in the 1770s, rose sharply (Figure 4). The late eighteenth and early nineteenth century has come to be known as the 'golden age of the handloom worker' (Hammond and Hammon 1919). Their high wages, however, became a target of inventors who sought to perfect the power loom to cut labour costs. This story was repeated in other handicraft trades.

Phase 2 Industrial Revolution: technology affected wages

The technological innovations of the Industrial Revolution had a dramatic impact on the labour market. The 'standard of living debate' dominates much discussion of the first half of the nineteenth century.[3] How could the high wage economy of the eighteenth century have given rise to apparently wide spread poverty in the nineteenth? Figure 4 shows the explosion in wage inequality in the Lancashire labour market. The 'golden age of the handloom weaver' around 1800 was followed by a collapse in their earnings as the power loom slashed the margin between yarn and cloth prices. Farm wages remained steady. The real wages of building workers rose consistently as did the wages of men employed in cotton mills after an initial dip during the French Wars. Eventually, handloom weavers were forced to give up the trade, and many redeployed to the remaining hand trades putting further down ward pressure on wages.

In 1820, handloom weavers amounted to 10% of the male workforce, so their fate was of considerable consequence in its own right. But they were not alone. Again and again, we encounter the same story: machinery was invented to do the work that a skilled artisan had previously done by hand. People with those skills continued in their trade (it was, after all, what they could do) even as their earnings dropped under the competitive pressure of increasingly efficient machinery. They sank into poverty, and eventually the trade disappeared. Framework knitting and pillow lace weaving are examples.

In 1589 William Lee invented a machine to knit stockings. It was powered by the operator and had more moving parts than the early spinning machines. It was impressively complicated. A narrow frame could make a dozen pairs of stockings per week, while a wide frame could produce that many in a day. In 1844, there were almost 50 thousand knitting frames in Great Britain. Many improvements had been made to the frame, which enabled it to knit more and more complicated patterns.

Pillow lace knitting was a separate industry. The lace knitters made a square of lace,

---

[3]The matter has always been contentious. An intense debate on the question with many contributions raged between the exchanges between Hobsbawm (1957) and Hartwell (1961) through Feinstein (1998), which brought that controversy to a close.

called a mesh, by sticking pins in the pillow and using them as anchors to weave the pattern with thread, bobbins, and crochet hooks. This was a domestic industry carried out in the knitters' homes and supported many thousands of women.

The industries were originally distinct, but their fates became entangled, as inventors contrived to improve the stocking frame, so it could knit lace. It was a difficult problem and was only solved by John Heathcote in 1809. At first, the machine wrought lace was crude, but over time, the process was improved so finer qualities of lace could be knit at lower and lower cost. At the beginning of the nineteenth century, women could make five meshes of plain net per minute on their cushions, and lace cost 100 shillings per square yard. The steam powered machinery of the 1850s knit 40 thousand meshes per minute, and the price of lace had dropped to 6d per square yard. In the face of this competition, the incomes of the pillow lace knitters collapsed, and eventually it became pointless for even the poorest woman to compete against the machinery. By 1860, 90% of the lace machines were steam powered. They were operated by men who had formed a trade union and earned high wages. The women who made lace in their cottages were gone.

The fate of the men who knit stockings and machine lace was also unfortunate. It was not difficult to learn to operate a knitting frame, so men who were forced out of other jobs like hand loom weaving flowed into the stocking and lace industries depressing earnings there. By the 1840s, poverty was endemic. The situation only improved when steam factories replaced the old knitting frames. Marc Isambard Brunel patented a steam powered knitting machine in 1816, but it was not successful. Circular machines were developed in the 1830s and became commercially viable after Matthew Townshend invented the latch needle in 1847. William Cotton's first patent was in 1846 and followed by half a dozen others in the next 25 years. He opened a factory in 1853 and sold knit fabrics and knitting machines. Steam powered factories proliferated. Productivity was much higher than in hand work, and wages rose. Modern collective bargaining also developed in the 1860s.

As one activity after another was mechanized, hand workers experienced falling earnings either because their own industry was mechanized, or because another was, and workers in it were driven into theirs. Hand workers as a whole suffered falling incomes. The average wage of the working class did not rise until the handicraft sector was replaced by factories.

The combination of rising real wages in expanding trades with the falling wages in the hand trades meant that the average wage level remained unchanged even as output per worker rose (Figure 5). The first half of the nineteenth century when this was occurring was the time when all social commentators–Malthus, Ricardo, Marx–thought that real wages would remain at subsistence no matter how much economic growth took place, and this period has been dubbed Engel's pause in recognition of Friedrich Engels' (1845) description of Manchester at this time (Allen 2009c).

Phase 3 The Age of Manufactures, 1867-1973: Wages affected technology in USA

Britain remained a leading industrial economy after the Industrial Revolution, but the dynamism of development shifted to the United States, and the country became the world leader in technology and manufacturing by the twentieth century. Hence, we shift our attention to the USA.

In 1869, the USA was not a mature industrial nation: 53% of the workforce was in agriculture and only 19% in manufacturing, but the latter were much more productive as manufacturing accounted for 15% of GDP versus agriculture's 22%. Manufacturing output grew rapidly thereafter and peaked in the early 1950s at 32% of GDP and 24% of employment.[4] The service sector's share did not change much, so the decline of agriculture was matched by the increase in manufacturing.

What determined the evolution of technology in this period, and how did it affect the labour market? The first issue to consider is the development of technology and its determinants, which include the evolution of factor prices.

In the mid-nineteenth century, American innovation was organized along the same lines as those of innovation in Britain during the Industrial Revolution. New technology was developed by inventors working on their own who aimed to profit from it by exploiting it in their own businesses or selling the right to use it to other entrepreneurs. However, as the period progressed, invention became more institutionalized. In 1876, Thomas Edison expanded his inventive capacity by founding the first industrial laboratory with about 60-80 employees. Many of the large American manufacturing firms produced by the mergers of the late nineteenth and early twentieth centuries quickly established industrial research laboratories (Chandler 1977, p. 375). These firms had more resources than many of the individuals who proceeded them. They also had commercial objectives that conditioned the course of R&D.

Much of this private R&D was aimed at product innovation. Inventions like the railway that transformed the lives of ordinary people made their first appearance towards the end of the Industrial Revolution. Even the poor were affected. The Duke of Wellington, for instance, objected to Brunel's Great Western Railway because 'it will only encourage the lower classes to move about.'[5] The same thing happened in India. When railways were built, third class ticket sales boomed, and the 'poor moved about.' By the late nineteenth century, developments like electric power, automobiles, petroleum, modern chemicals, and air craft began transforming life on a greater scale. Modern living quarters with their modern conveniences were invented (Gordon 2016). Product innovation was crucial in the growth process, for it sustained the continuous rise in demand for manufactures throughout this period: Had the consumption choices remained as they were in 1850, for instance, demand for manufactures would have been sated early on, and the economy would have evolved in a very different direction from that actually followed.

Government funded research also became important for the first time. In 1862, the Morrill Act provided for federally assisted land grant colleges in each state whose objectives included developing agriculture and engineering. In the same year the US Department of Agriculture was established. In 1887 the federal government began funding agricultural experiment stations in every state and in 1914 extension services to teach modern agriculture. In 1879 the US Geological Survey was established to survey and map the mineral resources of the country and promote their exploitation. These were scientific research organizations established to promote the settlement and economic development of the West. Their aim was not so much to promote the substitution of capital for labour as in Figure 3, but rather to raise the value of land and natural resources. The USDA and USGS are early examples of 'mission oriented R&D.' This type of organization has played an increasingly important role

---

[4] *Historical Statistics of the US,* series D167, D170, D174, F251, F254.

[5] http://www.bbc.co.uk/history/british/victorians/brunel_isambard_01.shtml

in guiding invention in the twentieth century and broadening the range of objectives it serves.

There is a fundamental economic reason for the state to fund basic research: New knowledge is a public good. In this context, a ‘private good’ is anything like an apple: only one person can eat it, and once that has happened, it is gone. In contrast, a ‘public good’ is one that can be consumed by an unlimited number of people: The Pythagorean theorem has been used in technical applications repeatedly for two and a half millennia without losing its power. Private goods can be effectively produced by the market system, but public goods like new knowledge are under produced since their creators cannot capture all of the benefits of their work. Pythagoras certainly did not receive much of the return from his theorem. Patents are a very imperfect device to deal with this problem over a limited time frame. Basic research is a public good. As a result, basic research is undertaken in universities or research institutes supported by public funds or charities. This support extends into basic technology. Hybrid corn, for instance, was developed in the United States in the first decades of the twentieth century. The basic biology was worked out by investigators at Michigan State University, the University of Illinois, and Harvard University. It was directed to practical ends by state experiment stations and the US Department of Agriculture. Only then did private seed companies begin to produce and market seed: Commercial production was first undertaken by a firm that was established by a USDA investigator.[6] Likewise the federal government in the twentieth century began funding basic research in medicine through the National Institutes of Health, which conducts its own research and funds many other projects. Only when drugs are developed do pharmaceutical companies enter the picture to market them. This has been the story with covid vaccines like the Oxford-Astra Zeneca and the BionTech-Pfizer producets.

Nevertheless, although product innovation and land value augmentation were important, much of the thrust of technological change in the period was aimed at cost reduction. In general, new technology was created with ever higher capital-labour ratios that produced ever more output per worker. We can study the evolution of this technology at both the industry and the macro level, and the same patterns emerge.

In his history of American management, Chandler (1977, pp. 240-283) wrote an overview of the development of manufacturing technology between 1870 and the First World War. He explains that the main objective in designing new plants was to increase ‘throughput,’ that is, output per factory. This was not done by increasing employment per factory, rather by increasing the capital in the plant, so that the work force could produce more per day. The iron smelting industry is a classic example. A key new technology was ‘fast driving,’ which meant blowing much higher volumes of air into the base of the blast furnace to increase production (Temin 1964). The results show up in the statistics for the industry: The number of workers per blast furnace establishment only increased from 122 to 183 between 1879 and 1914. Over the same period, horsepower per establishment increased ten fold from about 793 to 7639, while output per establishment jumped fifteen fold from 5552 tons per year to 81363 tons per year. Technology evolved similarly in industries as diverse as flour milling, cigarette rolling, petroleum refining, and distilling.

This pattern described by Chandler corresponds to the same pattern as technical change in the British textile industry during the Industrial Revolution: New technology raised capital per worker and pushed up output per worker by an even greater amount.

---

[6]https://tdaynard.com/2019/10/25/a-brief-history-of-the-hybrid-corn-industry/

Macro data for the nineteenth and twentieth centuries show the same pattern. Capital per worker and output per worker had changed little in countries that are still less developed. Development has taken place as a small number of pioneer countries have invented new technology that has created more capital per worker and even higher output per worker. Figure 6 shows this for a sample of countries between 1965 and 2010. The scatter of green dots in the upper right are the same countries that were the brown dots in the upper right of the 1990 distribution and also the blue dots in the upper right of the 1965 distribution. Aside from this movement, change has been minuscule. Once the rich countries had abandoned a low capital labour ratio for a higher one, there was been no increase in productivity at the low capital labour ratio: At low capital labour ratios, output per worker in poor countries in 1990 was no higher than it had been in 1820 in the USA or the UK, when they had similarly low capital labour ratios (Allen 2012). The behaviour of the macro ratios is the micro story writ large.[7]

Why did technology develop in this way? The answer is that economic development led to higher wages in rich countries, and the higher wages in turn made it profitable to develop technology with even higher capital labour and capital output ratios. It is important in this regard to distinguish between skilled and unskilled wages. Industries differed greatly in their mix of workers. In 1910, for instance, 48% of the work force in the iron and steel industry were unskilled workers as opposed to 14% in the automobile industry. Skilled and unskilled workers presented different challenges, but in the USA, at least, the movement of factor prices induced the substitution of capital for labour in both cases.

The incentives to mechanize depended on wages relative to capital prices rather than the cost of living, and Figure 7 shows this ratio for unskilled labourers. It was rising in the USA and also in Britain. There were two responses.

One was the invention and application of scientific management with its time and motion studies. In the classic account, Frederick Winslow Taylor (1911, pp. 39-44) explains how he pioneered the approach in the 1890s. The most common job of a labourer in manufacturing was to carry materials or product from one location to another. "Handling pig iron…is chosen [as an example] because it is typical of perhaps the crudest and most elementary form of labor which is performed by man. This work is done by men with no other implements than their hands. The pig-iron handler stoops down, picks up a pig weighing about 92 pounds, walks for a few feet or yards and then drops it onto the ground or upon a pile." At the Bethlehem Steel Company in 1898 a gang of pig-handlers "were loading on the average about 12-1/2 long tons per man per day. We were surprised to find, after studying the matter, that a first-class pig handler ought to handle between 47 and 48 long-tons per day." Taylor selected a German immigrant named Schmidt and offered him $1.85 per day

[7]The 1965 and 1990 data in Figure 6 are taken from Kumar and Russell (2002) who show fit frontier production functions to them and show that the only movement in the function occurs in the upper right hand corner. Allen (2012) extends these data back to 1820 for many countries and shows that it was always so. Jones (2005) develops a theory in which technologies are only a little more complicated than the Leontief isoquants in Figure 3 and proves that the aggregate production function is Cobb-Douglas so long as the distribution of new ideas is Pareto. Allen (2012) fits a CES function to the aggregate data from 1820 to 1990 and cannot reject the hypothesis that the function is Cobb-Douglas, although there are discrepancies at low capital-labour ratios, as noted.

instead of the usual $1.15 if he would load 48 tons per day. "You will do exactly as this man tells you tomorrow from morning till night. When he tells you to pick up a pig and walk, you pick it up and you walk, and when he tells you to sit down and rest, you sit down…And what's more, no back talk." Taylor allowed that "this seems to be rather tough talk. And indeed it would be if applied to an educated mechanic, or even an intelligent laborer. With a man of the mentally sluggish type of Schmidt it is appropriate and not unkind, since it is effective in fixing his attention on the high wages which he wants and away from what, if it were called to his attention, he probably would consider impossibly hard work." If this approach worked, the wage increase would raise Bethlehem Steel's profits and also the measured real wage of Schmidt and the other labourers.

Time and motion studies had limits as a cost cutting strategy, so businesses also employed the classic response to high wages–namely, mechanization. In the mid-nineteenth century, the ore, coke, and limestone to be charged into a blast furnace were first raised to the top of the furnace stack with a lift. The materials were transferred to wheel barrows, and labourers pushed them across a gantry to the top of the stack where they were dumped into the furnace. American iron firms replaced this system in the early twentieth century with 'skip chargers'. These were containers that were filled at the base of the furnace with raw materials and then hoisted up a track to the top of the furnace where they were automatically tipped and their contents dumped into the furnace stack. The labour of the top loaders was dispensed with and the savings in their wages paid for the skip charger (Allen 1977, Temin 1964, pp. 162-3).

With unskilled wages rising with respect to capital costs on both sides of the Atlantic, there was an incentive to mechanize that work in Britain and the USA. With respect to skilled labour, the incentives were greater in New World, for skilled wages rose much more there with respect to the cost of capital (Figure 8). This played out in industries like automobile manufacture that employed a high proportion of skilled labour. Henry Ford's Highland Park plant is the preeminent example. It was opened in 1910 to produce model T Fords, and it is most famous for being the site of the first moving assembly line in 1913. This invention accelerated throughput and displaced labourers. The bigger challenge, however, was to reduce the employment of high wage skilled machinists. This was accomplished through jigs, fixtures, and stops. General purpose machine tools that could perform many different tasks–and thus required the machinist to set the guides that controlled cutting and the depths to which drills would bore–were replaced with custom design machines in which pre-set jigs, fixtures, and stops controlled operation without the operator having to set them. Custom machines cost more than general purpose machines since a different design was required at every work station. This increase in capital intensity, however, allowed skilled machinists to be replaced by new immigrants from central European who had no machining experience (Meyer 1981, pp. 24-26, 44-53).

> The old time tool hardener was an expert. He had to judge the heating temperatures...The wonder is that he hit it so often...We introduced a system by which the man at the furnace has nothing at all to do with the heat. He does not see the pyrometer–the instrument which registers the temperature. Coloured electric lights give him his signals. (Ford 1922, chapter 6).

Conceptualization, for instance the ability to lay out the work and locate the jigs and set the stops, was separated from execution–merely pushing the metal through the machine

(Braverman 1974). The 'semi-skilled' worker was born.

The Highland Park plant was a trend setter and not an isolated case. It epitomized mass production. The manufacturing sector as a whole shows the same patterns. The share of skilled workers dropped from about 40% in 1850 to about 15% in 2010 with most of that drop happening before 1940 (Figure 9). There was at first a small rise and then a fall in the share of labourers/operatives. What is also striking, however, is the rise in white collar jobs–a theme we will return to.

There are several reasons for the rise in white collar jobs. With respect to the manufacturing sector, the decline in skilled work required a compensating increase in managerial and clerical activity as management assumed the conceptualization function that skilled workers had performed. Also skilled workers had often hired their assistants and subordinates, and these tasks were assumed by expanded personnel departments. Managers were also required to monitor and supervise the work of the semi-skilled workforce. In addition, the scale of business became larger to take advantage of the high throughput of advanced technology as well as to take advantage of the large national market created by the national rail system. The control of large organizations led to planning and cost accounting which entailed many office jobs.

Structural shifts in the economy also contributed to the growth in white collar employment. The rise of government with its tax systems and social welfare programs has entailed many clerical, managerial, and professional jobs. Higher incomes have led to shifts in consumer spending away from manufactured goods towards services like education and medical care, both of which required many professional employees.

Large numbers of clerical workers who were paid more than factory workers created an incentive to invent machines to save office labour. Type writers and dictating machines were early examples. A particularly interesting case is Herman Hollerith's invention of the electrical tabulating machine. It was first used to compile vital statistics in Baltimore in 1887 but its great breakthrough came when it was selected to compile the 1890 US census (Truesdell 1965, Austrian 1982). It is portentous in many ways including the fact that Hollerith's company became the core of IBM. Some European statistical agencies quickly took up the electrical tabulator as well as some American railway companies. An interesting case of non-adoption, however, is the Indian census. J.A. Baines (1900, pp. 50-1), the director, remarked to the Royal Statistical Society that there was no point using the electrical tabulator when Indian labour was so cheap. The economics of Hollerith's tabulator were much the same as Hargreave's jenny.

Phase 3 The Age of Manufactures in USA, 1867-1973: Technology and globalization influenced wages in USA

Despite–indeed, in part because of– the efforts of inventors to save money by inventing machines to substitute capital for labour, real wages rose rather than fell between the mid-nineteenth century and 1973. Figure 12 shows that real average earnings per person in the labour force rose at the same rate as real GDP per worker from 1869 to about 1950. Both continued to grow thereafter, but the real wage rose somewhat less rapidly. The 'stylized fact' that wages and output per worker grow at the same rate is a generalization of the history of this period in the USA and also in Britain.

The process was, of course, more complex when examined in detail. It is important to distinguish skilled from unskilled labour. Figure 13 shows unskilled wages expressed in 1905 British pence in the USA and UK. The wages rates of unskilled workers in the UK and USA were strikingly similarly until the First World War. Skilled wages in the two countries were also similar in the ante bellum period. However, after the Civil War, skilled wages rose more rapidly in the USA, and a large gap emerged by the end of the nineteenth century (Figure 14).

Another notable development occurred after World War I. British wages stagnated, while American wages lept ahead. By 1940, American factory operatives and unskilled workers were making 25 - 50% more than British skilled workers (Figure 15). (American skilled workers were making even more than that.) This marked the birth of the so-called 'American middle class.' Their wage gains continued after World War II and only ceased in 1973. Henry Ford summarized the impact of the new technology as follows: "I have heard it said, in fact I believe that it's quite a current thought, that we have taken skill out of work. We have not. We have put a higher skill into planning, management, and tool building, and the results of that skill are enjoyed by the man who is not skilled" (Ford 1922, chapter 5).

Ford was right that technical change played an important role in explaining the course of American wages, but other factors were also at play. Some affected the demand for labour and others the supply.

On the demand side, an important factor that sustained rising wages was the expansion of the American population as the continent was settled. Between 1850 and 1950, the population grew from 23 million to 152 million. Globalization played a role in this expansion. The international (read: British) demand for American grain and beef was buoyant throughout the century. For it to have been profitable to have settled the West, the price of wheat or cattle at the point of production on the frontier had to be high enough to induce labour to give up the chance of earning high wages in the east of the country and move west. The construction of ever more railways meant that more and more homesteads met this condition. Even after the frontier was closed, the West was not fully settled, and the population and economy continued to drift westwards well into the twentieth century. The Second World War gave a further boost to the great American boom, and the country enjoyed several decades of economic ascendancy in the post-war era.

The effect of the continual rise in population at high and rising wages combined with waves of product innovation was the fastest growing consumer demand in the world. Manufacturing expanded to meet it, and employment of production workers grew almost continuously from 1850 to 1979 (Figure 16). The depression of the 1930s, of course, disrupted this expansion, and there was small cyclical fluctuation around the trend, but, in general, the trajectory was ever upward.

Technical progress also contributed to rising wages throughout the period 1867-1973. The replacement of skilled jobs by semi-skilled jobs might appear to be a counter example, but the rapid expansion of the manufacturing sector meant that the demand for skilled labour was rising in the twentieth century, albeit at a lower rate than manufacturing employment as a whole. In addition, the elimination of labouring jobs as material transport was mechanized in conjunction with the creation of new semi-skilled jobs meant that skill level over all was rising. As factory labour became more productive, competition among firms for workers led to rises in real wages.

The supply of labour also affected the evolution of wages. Supply changed after the first World War because immigration policy changed. Before World War I, there was no restriction on immigration from Europe. As the West was settled and the manufacturing sector expanded, the demand for both skilled and unskilled labour increased. The USA lacked the system of industrial apprenticeships that sustained Britain's supply of skilled workers (Elbaum 1989). It is hard to escape the conclusion that the supply of unskilled labour from the farms of eastern and southern Europe was much more elastic than the supply of skilled labour from the USA itself–even with some assistance of immigrants from the UK and northwestern Europe (Goldin 1994, O'Rourke 2019).[8] As a result, the rising demand for labour caused the wages of skilled workers to rise, while the immigration of farm labourers dampened any corresponding increase among the unskilled. This 'open door' immigration policy changed after 1921. Immigration no longer put a lid on the wages of unskilled and semi-skilled wages, and they rose closing the gap with skilled wages.[9] Thus began the 'great compression' of the 1930s and 1940s (Goldin and Margo 1992).

Labour unions also contributed to the great compression. Unskilled workers in the manufacturing sector were unionized during the 1930s. Previously, unions had often been weak and generally involved only skilled craftsmen. New Deal labour legislation created a favourable environment for organization, and the CIO succeeded in unionizing most manufacturing workers. Wage negotiations tended to reduce wage inequality within the sector.

A final factor to consider is education. In their influential analysis of *The Race between Education and Technology* Goldin and Katz (2008) maintain that technical change throughout the twentieth century has increased the demand for educated labour. Their evidence for this claim in so far as factory workers are concerned is that production workers with more schooling earned higher wages than those with less schooling early in the twentieth century. They contend that wage inequality decreases when the supply of educated workers increases. The spread of high schools in the USA during the early twentieth century was rapid enough to explain the fall in the skill premium. For emphasis, they dubbed the twentieth century the 'human capital century.'

It is difficult on the face of it to reconcile the Goldin-Katz view of the twentieth century with the de-skilling view of mass production advanced here. It is true that the educational level of the American work force has risen substantially, and conventional growth accounting attributes a lot of productivity growth to the rising educational level of the work force (Denison 1962, Jorgenson, Griliches 1967). However, most accounts of factory work emphasize that increases in mechanization made work more boring (Chinoy 1955, Bright 1958a, 1958b, Meyer 1981). One of the complex aspects of a craftsman's job was laying out the work. Knowledge of geometry and mathematics helped do that quickly and well. A craftsman could have made use on the job of the Euclidean geometry he had learned in high school. When the layout, however, was built into a machine, the need for that knowledge evaporated. Perhaps Bowles and Gintis (1976) got it right when they argued that what high school really taught students was how to follow instructions and fit into a routine.

Phase 4: The Shift to Services in USA, 1973-2020: wages affected technology

---

[8]This view has been contested, e.g. by Goldin and Katz (2008).

[9]The end of the mass immigration of European farmers created the opportunity for African-Americans to leave their farms in the South and move to factory work in the North (Collins 1997).

If the popular media and blogosphere were to be believed, we are now living through a period of unprecedented technological change. Terms like the 'fourth industrial revolution' encapsulate the view that IT and artificial intelligence are remaking the economy. In addition, the outsourcing of production to China and other developing countries highlights the (possibly growing) importance of globalization. The significance of these developments can only be assessed by locating them within the overall evolution of the economy.

The American economy has been transformed since the 1960s in several important respects. A fundamental change is the collapse in manufacturing and the rise of the Service sector. Figure 18 summarizes some of the important trends in employment in the non-agricultural economy since 1900. In the first decades of the twentieth century, manufacturing accounted for almost 40% of the jobs. Together with its near relatives–mining, construction, and transportation (read: railways)– modern industry accounted for over 60% of the non-farm economy. These sectors were closely linked and shared many of the same industrial relations practices and generated similar wages. The government also tended to match these wages. "Modern industry" was a big enough share of the economy to sustain the American middle class, which is why it is important.

All this has change. The share of employment in manufacturing and related sectors declined modestly between 1920 and the 1960s, but was still large enough to provide widespread prosperity. Since the 1960s, the decline has been precipitous. By 2010, manufacturing employed only 9% of the non-farm workforce. Including mining, construction, and transportation only brings the share up to 19%. Government employs only 17%. All of the rest was private services. These ranged from doctors, teachers, and business consultants to waitresses, check out clerks, hospital orderlies, and parking lot attendants. The managerial and professional jobs generally require technical training or university degrees, while the sales and low skill service jobs do not. As we will see, the former have had rapidly rising real incomes in the last fifty years, while the latter earn low incomes that have been static in many (but not all) cases. The shift to a service economy means that the standard living of the bulk of the American population is no longer determined by the wage level in manufacturing, transport, or construction, but rather in services. And wage inequality is very great in that sector.

What factors account for this enormous structural change? I begin with manufacturing. The Great Depression aside, we saw earlier that employment in manufacturing increased steadily after 1850. It peaked in 1979 at 20 million jobs and has since fallen by half for a loss of almost 9 million (Figure 16). Declines have been uneven across industries. Apparel, footwear, and textile mill products peaked earlier and have suffered declines on the order of 90% in employment. Primary metals have lost 70% of their peak number of jobs. On the other hand, chemicals, fabricated metals, and transportation equipment have seen only small falls, and employment in food and beverage production is at an all time high. Computers showed explosive growth for several decades, but in recent years employment in that industry has been falling as well.

Why did this happen? Globalization is an obvious suspect, for the spread of industrialization to poor, low wage countries has made them competitive in cloth, apparel, and footwear, and imports of these products explain much of the decline in employment in these industries. Imports now account for almost 90% of the American market in footwear and apparel. Imports have also made inroads in cloth (41%), furniture (30%), computers (36%), and electrical machinery (58%). In other industries like primary metals, non-electrical machinery, paper, printing & publishing , however, import penetration is generally less than

10% and often negligible and yet employment has fallen 50-75%. Clearly, something besides imports from low wage countries is involved.

Aggregate statistics point to the same conclusion. Total imports of manufactures equalled 12% of shipments of manufactures in 2016. If American factories had expanded to replace those imports and employment increased proportionally, manufacturing jobs would have grown by 1.4 million workers. This figure is less than the 2 million workers suggested by the more complicated analyses of Autor, Dorn, and Hanson (2013, p 2140) and Acemoglu, Autor, Dorn, Hanson, and Price (2016, s145). These take account of re-allocation, inter-industry linkages, and general equilibrium effects. None of these estimates is large enough to explain the decline in manufacturing employment.[10] In addition, declines in manufacturing employment started in 1970 or earlier–when imports of manufactures were either non existent or inconsequentially small. Furthermore, as Feenstra, Ma, Sasahara, and Xu (2018) point out, the US is a major exporter of manufactures and increases in exports raised manufacturing employment by about as much as imports reduced it. If the issue is the impact of greater globalization on US manufacturing employment, as it is, then the export side must be included, and that offsets the import side.

Perhaps technical change has been the culprit. Production processes have, indeed, been redesigned to be more capital intensive. Between 1950 and 2014, the wage of a US production worker relative to the Penn World Table cost of capital more than doubled, and the corresponding ratio in Britain increased almost four fold. The capital labour ratio increased almost seven fold between 1965 and 2014 in the UK, while it tripled in the USA. Between 1970 and 2016, output per worker in US manufacturing increased almost five fold.[11] If all else other than productivity had stayed the same, then today employment in manufacturing would be almost five times its present level.

What about computers and robots? The post World War II period has been marked by the proliferation of computer and IT systems and their integration into business practice. These represent the substitution of capital for labour at an accelerated rate. The substitution has been driven by rapidly falling prices: Computers and related equipment dropped in price (adjusted for quality) by about 20% per year between 1973 and 2010. Semiconductor and software prices also fell although not as rapidly. Between 1947 and 1973, computers made little contribution to the growth in aggregate US total factor productivity growth or the decline in manufacturing employment. Since 1973 TFP growth in the American economy has been driven mainly by productivity growth in the IT sector itself and in the industries that use IT extensively, which are mainly services. Labor productivity has risen in manufacturing outside of IT mainly because of increases in capital intensity (Jorgenson, Ho, Samuels 2016).

Since around 1990, the installation of industrial robots has proceeded very rapidly in east Asia, north America, and Germany. This trend was driven by a steep fall in the quality adjusted price of robots. Even with production workers realizing no increase in their real (consumption) wage, the rate of return to installing robots has risen dramatically. Robots are

---

[10]Pierce and Shott (2016) argue that the US's granting Permanent Normal Trade Relations to China in 2000 explains the18% decline in American manufacturing employment between 2000 and 2007.

[11]In this calculation real gross output is divided by employment. A smaller increase is obtained by dividing real value added by employment.

promoted on the grounds that they are a cost effective way of substituting capital for labour in manufacturing, so factor prices are integral to their diffusion and invention. Robots are an accelerated iteration of the technical change that has characterized the past two centuries.

Another development in management practice, reminiscent of Taylorism, has also made a small contribution to the reduction in measured employment in manufacturing, and that is domestic outsourcing. It is not unusual now for employers to replace directly employed workers with workers provided by service firms or on other irregular contracts, in which case the worker is tallied by the statistical agencies as being employed in the service sector rather than in manufacturing. This practice is most common in education, health, construction, and business and personal services. Katz and Krueger (2019) estimated about 11% of workers in manufacturing were employed on these contracts.[12] Some of these would have been tallied (misleadingly) as service sector workers. If they all were so tallied, they would have totalled about one million in 2016. This is only a small fraction of the decline of production employees, let alone all employees, that the US manufacturing sector has experienced.

There is a subtle issue in assessing the role of technical change in the decline in manufacturing employment. Technical change means that output per worker has increased. That occurred in the Industrial Age and was then manifested as an <u>increase</u> in employment accompanied by an even greater proportional <u>increase</u> in output. Today productivity is also rising but manufacturing employment is <u>declining</u>. Why the difference? The answer is that demand for manufactures is only slowly increasing. In aggregate this has not been due to the replacement of domestic production by imports, but rather by a fundamental shift in the structure of demand in the economy. In the USA, the structure of consumer demand has shifted from manufactures to services, and that has depressed the growth rate of manufacturing output. From 1929 until 1970, goods rather than services comprised at least half of what consumers bought. By the late 1980s the share had dropped to 40% and today it is 31% (Figure 19). The price of services was rising with respect to the price of goods, which indicates that the shift to services reflected a demand increase in their favour. This is often attributed to Engel's law–the observation that as people become richer their consumption of food levels out while their consumption of manufactures increases until it, too, decelerates and the consumption of services rises.

It is not enough to assume that the demand for manufactures automatically weakened by treating Engel's law as a deus ex machina. The demand for manufactures was sustained by product innovation in the late nineteenth and much of the twentieth centuries–it was the invention of bicycles, cars, televisions, and so forth that kept Americans buying manufactured goods. Product innovation has continued since the second World War. Play stations and smart phones are in the same tradition but have not had the decisive importance of the earlier inventions.

Many new products have their roots in mission oriented research (Nelson and Wright 1992, pp. 1950-4). Many of the electronics innovations are spin offs of technology developed for military purposes. All of the major features of the iphone–touch screens, for instance, and GPS–are commercial applications of technology developed under US defence contracts (Mazzucato 2013). The original purpose was the solution of a military problem and not cost

---

[12]The surveys analysed by Dorn, Schmieder, and Spletzer (2018) point to a similar conclusion.

reduction or commercial advantage.

Modern drugs and medical instruments are also the results of mission oriented research in the health area. These discoveries have played a fundamental role in shifting consumer demand. While they are produced by manufacturing firms, most are dispensed through the service sector. The share of consumer spending on health care has risen from 2% in 1929 to 16% today, and that would not have happened without the advances in medical technology that prompted the expenditures. The growth of income in the health sector was also due to its organization, which has led to very high prices and the promotion of high cost interventions (Case and Deaton 2020).

Other innovations that promoted the sectoral shift include the IT revolution that has created many new jobs managing or exploiting information technology (Acemoglu and Restrepo 2018, 2019). Many of these jobs are in the service sector, and schools and universities–components of the service sector–have expanded to train people in the new technology wherever it be used. In addition, globalization played a role as people's taste in cuisine was broadened to include eating dishes from around the world. A rising demand for travel was a counter part.

These changes in spending shares mattered. Had the share spent on goods stayed at 50%, the consumption of manufactures by consumers would have been two-thirds greater than it is now, and that would have translated into a commensurately greater manufacturing sector and a higher level of employment had import penetration remained as it is. Under these circumstances, there would not have been much of an employment decline in manufacturing employment.

Phase 4 The Shift to Services in the USA, 1973-2020: technology and globalization affect the labour market

The period since 1973 has much in common with the Industrial Revolution. In the USA, for instance, where the trends are most intense, the average real income of the labour force has risen slowly and fallen much behind the growth in output per worker (Figure 20). As a result, labour's share of the national income has dropped from 56% to 46% between 1970 and 2016 (Figure 21). This is the labour market manifestation of the rise in overall income inequality that has defined the period. Wage inequality has also increased dramatically. Since 1973 the real wages of production and non-supervisory workers have fallen slightly, while the incomes of managerial and profession workers have skyrocketed (figure 22). These trends are similar to those in Britain during the Industrial Revolution.

There are also parallel causal explanations of these trends, although there are also important differences. What the two periods have in common is the emergence of a new production structure and the eclipsing of the old. During the Industrial Revolution it was the rise of the factory that drove handicraft cottage producers out of business. Post 1973, it is the rise of the service sector and the decline of manufacturing.[13] There is an important difference here, however; the factories of the industrial revolution produced the same or similar products to those of the handicraft sector, and the factories won by producing these goods at lower

[13]Temin (2017) offers another two sector model with a different division but many of the same themes.

cost. This was creative destruction with a vengeance. Today, however, the service sector produces a different kind of output from manufacturing (cataract operations, for instance, versus paper towel dispensers), and the shift to services represents a shift of demand in that direction–creative destruction by subterfuge.

The problem with the decline in manufacturing and the rise of the service sector is that it depresses wage growth for less skilled workers. Table 2 summarizes annual earnings data for 1972, near the peak of the real wage series of production and non-supervisory workers, with 2017, the most recent year available. The focus is on semi-skilled operators in manufacturing in view of their significance as a corner stone of the American middle class and low skilled service employees like retail clerks, cashiers, waitresses, bartenders, cleaners, nursing aides, and hairdressers. Semi-skilled manufacturing workers who lost their jobs often moved into these service jobs, as did young people entering their labour force who might in an earlier generation have aspired to semi-skilled factory work. Comparisons are clearest for full-time, full-year employees (FTFY), but figures for part time workers and all workers are included since part-time work is prevalent, especially in the service sector, and many workers end up with part-time jobs who would prefer full time work. In both years, the manufacturing jobs paid more than the service jobs. This is not due to differences in human capital like education attainment, which was, in fact, slightly higher among the service workers and which does not explain the wage differentials when entered in standard wage regressions. Nor did other variables like race, ethnicity, or nativity play important roles. Probably unions played a role in raising manufacturing wages in 1972. Their importance was substantially lower in 2017, and yet their decline did not result in a real wage collapse in that sector. Why semi-skilled manufacturing wages still earn a premium is a puzzle.

Whatever the solution of that puzzle, Table 2 highlights key changes that have characterized the low wage half of the labour market in the past fifty years. If we compare wages in 2017 to those in 1972 within occupations, we observe relatively favourable patterns. Men certainly did worse. Those working full time in manufacturing saw their real earnings rise by about $2 thousand, while their counterparts in low skill services saw their earnings drop by about the same amount. These were small changes in percentage terms, so the main conclusion is ‘no change’ in the real earnings of men over the period. This is not a good result.

The results for women were more satisfactory. Women fully employed in semi-skilled manufacturing jobs achieved an increase of $11 thousand (40%).[14] Women in services did not do quite as well, realizing a rise of $5 thousand (22%). This performance was much better than that of men and may reflect the effect of affirmative action and equal pay policies.

The problem is that most workers did not have it this good. The reason is the big shifts in employment structure. Very few women worked in manufacturing and achieved the wage gain shown because most of the semi-skilled jobs for women in manufacturing had disappeared by 2017, so the women (or, to be more exact in view of the time interval, their daughters) worked in services. The earnings of fully employed women in services in 2017 compared to manufacturing in 1972 shows a gain of less than $1 thousand.

For men, the situation was far worse. Comparing manufacturing in 1972 to services in 2017 shows a real annual earnings decline of almost $10 thousand or 20%. The shift to the

[14]The substantial real wage increase for full time full year women in manufacturing is of little moment since there are very few such jobs left anymore.

service economy has been a serious setback for men in the bottom half of the wage and salary distribution.

Phase 4: The Shift to Services in the USA: Policy Options

The rise in inequality has become a major political issue in both the United States and elsewhere. There are a variety of proposals on the table to address it. The following are options in order of increasing activism:

1. Keep Calm and Carry on

The do nothing approach can be justified in two ways. One is libertarianism. Libertarians contend that state action involves coercing people one way or another, and that coercion is unacceptable except in some narrowly defined circumstances (Friedman 1962). A counter argument is the ‘positive freedom’ critique that notes that the strained circumstances of the poor leave them little freedom in practice, so total freedom might by increased by forcing the rich to pay taxes (a reduction in their freedom) and giving money to the poor.

The do nothing response may also be rooted in the idea that everything has worked out for the best in the past and so probably will in the future. This is what happened eventually during the Industrial Revolution, so perhaps history will repeat itself.

Such optimism receives some support from the polarisation analysis of Acemoglu and Autor (2011, 2012) and Autor and Dorn (2013). Their approach begins with the well founded generalisation that highly paid managerial and professional jobs have been increasing and their incomes rising and adds to this the observation that the personal service jobs at the bottom of the wage distribution have also been increasing both relatively and absolutely and have also experienced rising wages. Both wages and numbers could both be increasing only if demand for these jobs was rising, and the authors locate the cause of that increase in the rising incomes of the upper classes, who demand more of the personalized services provided by these service jobs. Table 1 offers little support for this view in the case of men (where the earnings of full time men in services have fall between 1972 and 2017) but more so in the case of women where the income of full time workers has increased by 22% over the same period. How much ‘personalized service’ is offered by a Walmart check-out clerk or food court waitress is not so obvious, however. And, the wage of this broad category of workers has fallen behind the growth in aggregate productivity growth over the period.

2. Tariffs, stop immigration, build walls

This is the approach of President Trump. It attributes the economic deterioration experienced by many Americans to two causes. The first is imports of manufactures from China and the outsourcing of production to Mexico. The solution was the renegotiation of North American Free Trade Agreement and tariffs on goods like steel and aluminum to maintain higher prices of these goods in the US. The second cause is immigration from low wage countries in Latin America. Restricting legal immigration and building walls along the Mexican border to prevent illegal immigration are policies to address that. The Trump approach ignores many of the factors like technical change and the rise of services that are arguably more important causes and may also be counterproductive: raising the price of steel in the USA benefits steel producers but harms the engineering firms that use steel as an input.

3. More education

This is a classic liberal approach. The argument is that new technology has shifted the demand for labour to more educated workers, and the problem is a failure oft the supply to keep up. In practice, this means raising the educational level of the service workers. Something that gives us pause is that the educational attainment of this groups has already increased substantially. In 1972, most had not completed high school, while today most of them have high school diplomas, and some have further education, which brings higher earnings, but not enough to reach factory standards. Higher educational and professional qualifications would presumably require a large scale transfer of waiters and clerks to professional jobs. Is this really feasible?

4. Green Industrial Revolution

The claim is that the increase in inequality can be address with the same policies aimed at reducing carbon emissions. These include refurbishing the housing stock to reduce energy loss, replacing fossil-fuel powered electrical generating capacity with renewable energy, and shifting land transport from gasoline to electric vehicles. These activities are presumed to require the creation of many well paying craft jobs in industry and construction. Initiatives along these lines are part of Biden administration policy. At present, plans are too vague to know whether or not the overall employment structure would shift as a result.

5. State initiatives

A suite of market interventions are available to address issues relating to labour markets and inequality. Many are standard European social democratic policies that have been eschewed by American conservatives and many liberals. These includes:

5-1 higher taxes on wealthy individuals and corporations

For much of the twentieth century, individual and corporate tax rates were much higher than they are presently. They were cut to present levels during the conservative ascendancy following the stagflation of the 1970s. There is no indication that higher taxes stifled economic performance or that lowering them has improved performance, so they could be raised again. Possibilites range include higher personal and corporate tax rates, elimination of tax loop holes, a Picketty-style capital tax.

5-2 break-up or regulate monopolies.

Policies along these lines have been pursued since the Interstate Commerce Commission was established in 1887 and the Sherman Antitrust Act was passed three years later. These interventions were regarded as harmful or ineffective by conservative economists, but have come to the fore in the context of new internet giants like Facebook, Google, and Amazon, who exercise great market power and avoid paying taxes by shifting profits to subsidiaries in low tax jurisdictions.

5-3 transfers to lower income groups

The states and federal government have given welfare payments to a variety of low income groups through a variety of programs. Some programs like the Earned Income Tax Credit have been aimed at the 'working poor.' These could be strengthened. One option is a guaranteed annual income. Another is payments directed at children. The Biden Administration's American Families Plan is an example.

Income support for low income families with children can be justified as an plan to reduce inequality. It is important that it can also be defended as a plan to increase the rate of economic growth. Indeed, well designed studies of the effectiveness of these programs show that they lead to substantial increases in life time income for people who have been supported. While these programs take a long time to produce benefits, the rates of return are very high (Bartik 2011, Heckman 2013, Hendren and Sprung-Keyser 2020).

5-4 raise the minimum wage

The proposal to increase the federal minimum wage to $15 per hour has been widely discussed. Recent research supports the feasibility of higher minimum wages for raising the incomes of low wage service workers. The argument against such increases is that firms expand employment to the point where the wage equals the value of the marginal product of labour, in which case, a higher wage causes firms to reduce employment to maintain that equality. Attempts to measure the predicted reductions have yielded mixed results. However, a recent comprehensive study indicates no negative employment effect among service workers; rather, increases in the minimum wage cause firms to raise low wages to that minimum and, indeed, to raise the wages of some workers earning above it (Cengiz, Dube, Lindner, Zipperer 2019). There is scope for raising minimum wages without adverse employment effects.

The absence of an adverse employment effect highlights an important feature of the labour markets concerned, namely, that low wage workers were paid less than their marginal product (Case and Deaton 2020, p. 237). This situation arises when firms have monopsony power manifest in the proliferation of noncompete agreements (even among fast food worker!), the rise of domestic outsourcing, the decline of trade unions, and outright collusion (Krueger 2018).

5-5 extend collective bargaining

If there is scope for legislation to raise wages, then there is also scope for trade unions to do the same thing. The 1935 National Labor Relations Act required employers to bargain in good faith with any trade union chosen by their employees. This law facilitated the unionisation of the mass production industries of the USA, and the wages they negotiated sustained the American middle class. Beginning with the Taft-Hartley Act of 1947, the rights of workers to easily form unions have been gradually restricted, and these changes in law have contributed to the dramatic reduction in the share of the private sector work force that can bargain collectively with its employers. Changing labour law could increase the share of the work force in trade unions and that could raise wages in manufacturing and some service industries.

5-6 public or cooperative ownership of business

Extending public ownership used to be an objective of many workers, but fell out of favour even with European socialist and labour parties in the 1980s and 1990s. While many on the left wing of the democratic party claim to be 'socialists' what this means is less than clear.

While support for socializing the private business sector is limited, it is worth noting that much of the invention process is already socialized. The reason, as discussed previously, is that new knowledge is a public good that cannot be efficiently produced by private firms. Presently, the relationship between publicly funded research and privately executed applications is uncoordinated and patch. If it were recognized that the basic R&D can only be comprehensively carried out if it is publicly funded, then it might be possible to extend public research to address technological bottlenecks in areas like climate change.

Conclusion

The last four centuries have seen alterations in the relationship between growth in output per worker and the real wage. In the run up to the Industrial Revolution (1620-1770), both increased, and wages tended to converge upwards. High wages relative to capital prices precipitated the invention of capital-intensive factory production. Competition between the new factories and the remaining handicraft producers during the Industrial Revolution (1770-1867) led to rising inequality in wages and flat average real wages overall. Once the handicraft sector was competed out of existence by he factories, a long period of fairly steady growth in output per worker ensued from 1867 to 1973. The endless invention of new manufactured goods was essential in maintaining buoyant demand for so long. Real wages rose in pace with overall labour productivity. By the end of the nineteenth century, the real wages of skilled workers in the USA, in particular, were leaping ahead, and the chance to eliminate their expensive jobs led to the invention of mass production and the routinization of work–a process that continued through the 1960s. By the 1930s, the spread of collective bargaining throughout manufacturing created an industrial relations system through which the manufacturing worker force could secure increases that matched productivity growth. This favourable situation lasted until about 1973, when the growth in manufacturing output slacked markedly as consumers shifted spending towards services. Imports of manufactured goods from low wage countries and domestic out sourcing reinforced this trend. Slowly growing manufacturing output in conjunction with the continual substitution of capital for labour via new production technology meant that the number of manufacturing workers went into long term contraction. More and more of the new work force was absorbed in the new ascendant sector–services. While it provided many high wage technical and professional jobs, it also recruited large numbers of workers (who would have become factory workers in previous generations) into low paid jobs, many of which were part time. Weakness in the labour market contributed to a rise in profits, which now originate mainly in services. Responding to this new economy is the challenge of the future.

Table 1

The evolving economic structure of pre-industrial Europe, 1500-1750

We can see how the economies of European countries were transformed between 1500 and 1750 by dividing people into three categories depending on where they lived and what they did. The categories are 'urban' (those living in settlements of more than 5 thousand people), 'agricultural' (those living outside of urban settlements and farming the land), and 'rural, non-agriculture' (those living outside of urban settlements and doing jobs other than farming). Examples of the latter include the village clergy, monks, domestic servants, carters, miners, spinners, weavers, and other craftsmen. The table below shows these divisions for the principal European countries following modern boundaries. The percentages add to 100% for each country in each year. The countries that changed the most were the commercial powers of northwestern Europe.

	1500			1750		
	urban	rural nonagri-culture	agri-culture	urban	rural nonagri-culture	agri-culture
greatest transformation						
England	7%	18%	74%	23%	32%	45%
significant modernization						
Netherlands	30	14	56	36	22	42
Belgium	28	14	58	22	27	51
slight evolution						
Germany	8	18	73	9	27	64
France	9	18	73	13	26	61
Austria/Hungary	5	19	76	78	32	61
Poland	6	19	75	4	36	60
little change						
Italy	22	16	62	22	19	59
Spain	19	16	65	21	17	62

Source: Robert C. Allen (2017, pp. 19-20).

Table 2

Earnings of Low Skill Workers in US Manufacturing and Services

	Semi skilled manufacturing	Low skilled services
MEN		
1972		
FYFT	$49302	$41470
part time	10622	7141
all	41261	22624
2017		
FYFT	51075	39364
part time	20340	10215
all	45983	27914
WOMEN		
1972		
FYFT	28904	24342
part time	7904	7215
all	19942	11662
2017		
FYFT	40359	29745
part time	23458	10945
all	34927	20311

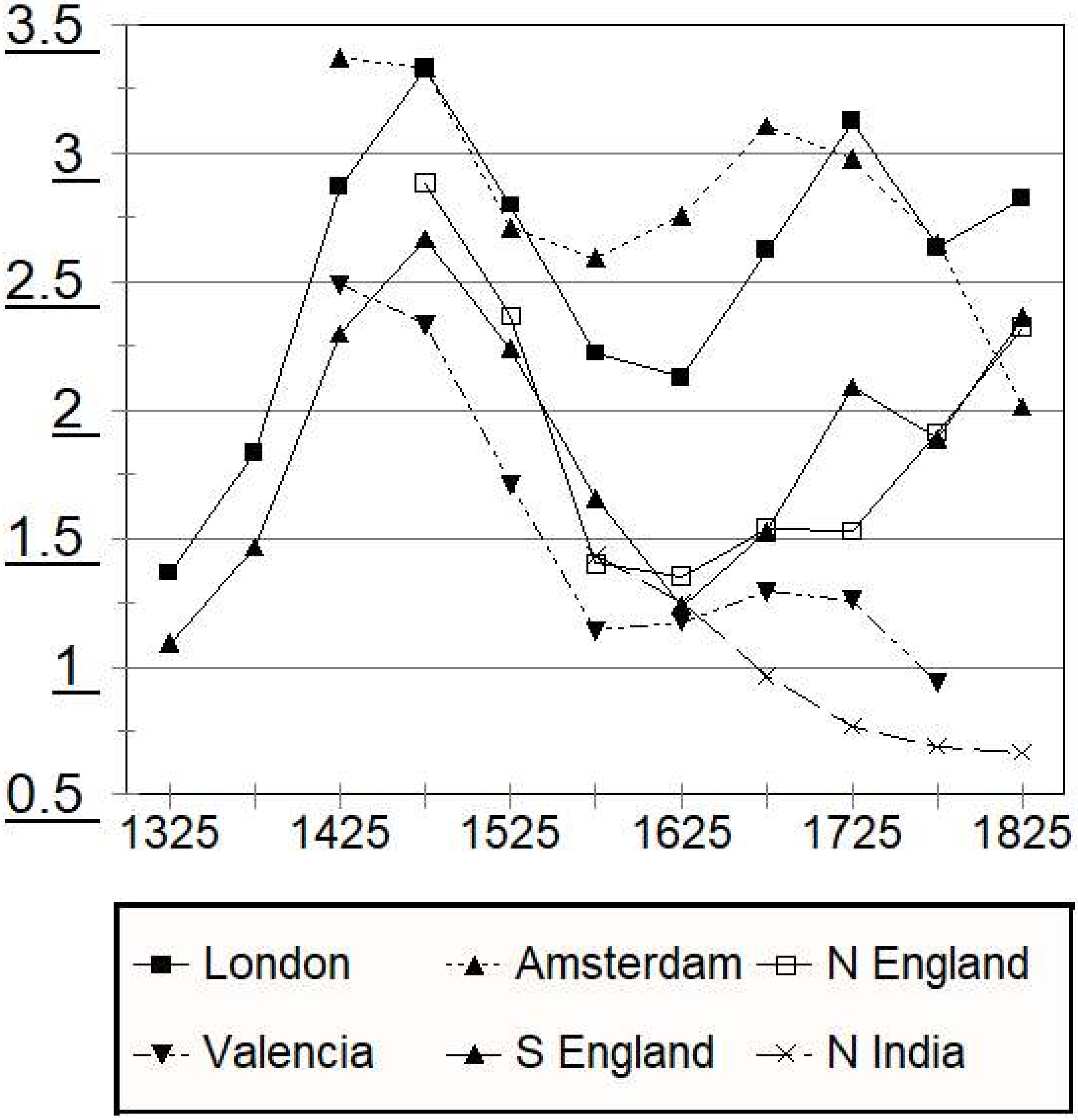
Notes:
FYFT = full year, full time
Full time, part year workers are included in ‘all’ but not separately tabulated.

Source:

Current Population Survey, Annual Social and Economic Supplements for 1972 and 2017 (Flood et al. 2020)

Figure 1

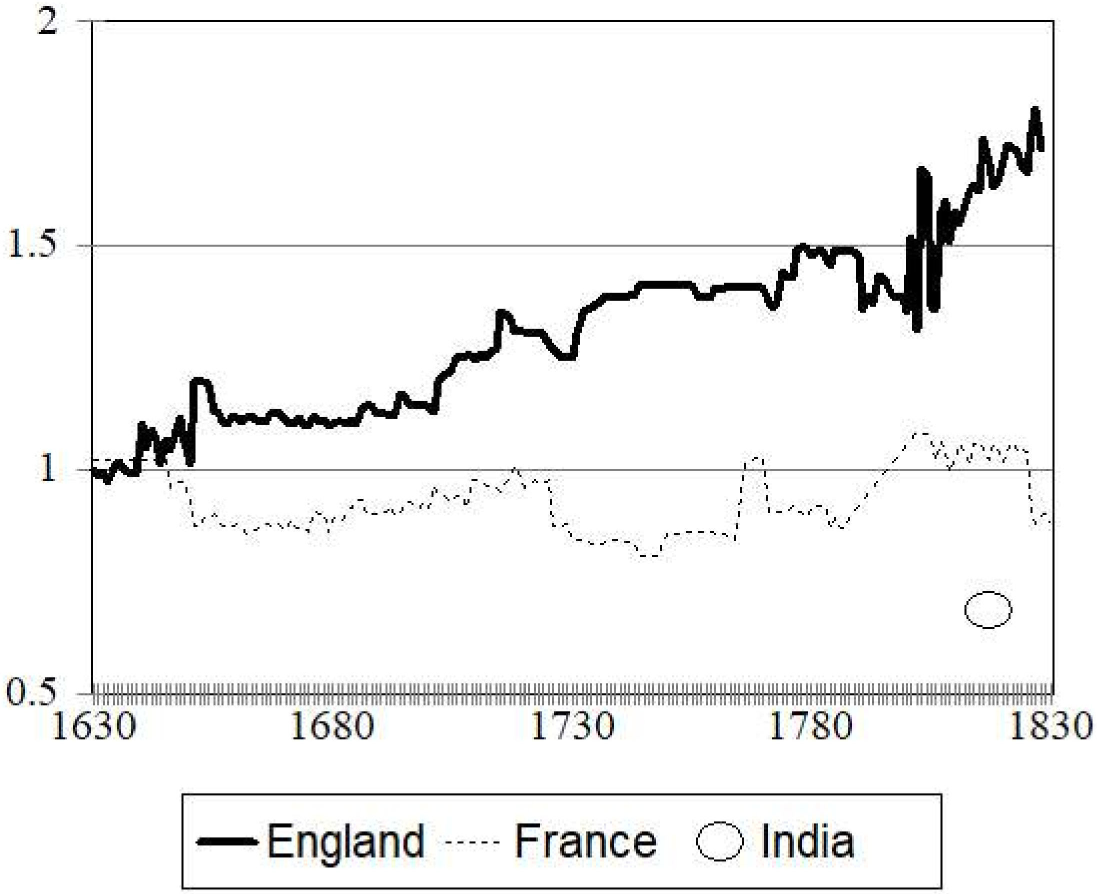
Real Wages in England, Europe, and Asia



sources are detailed in Allen, Bassino, Ma, Moll-Murata, and van Zanden (2011) and Allen (2015, p. 8).

Figure 2

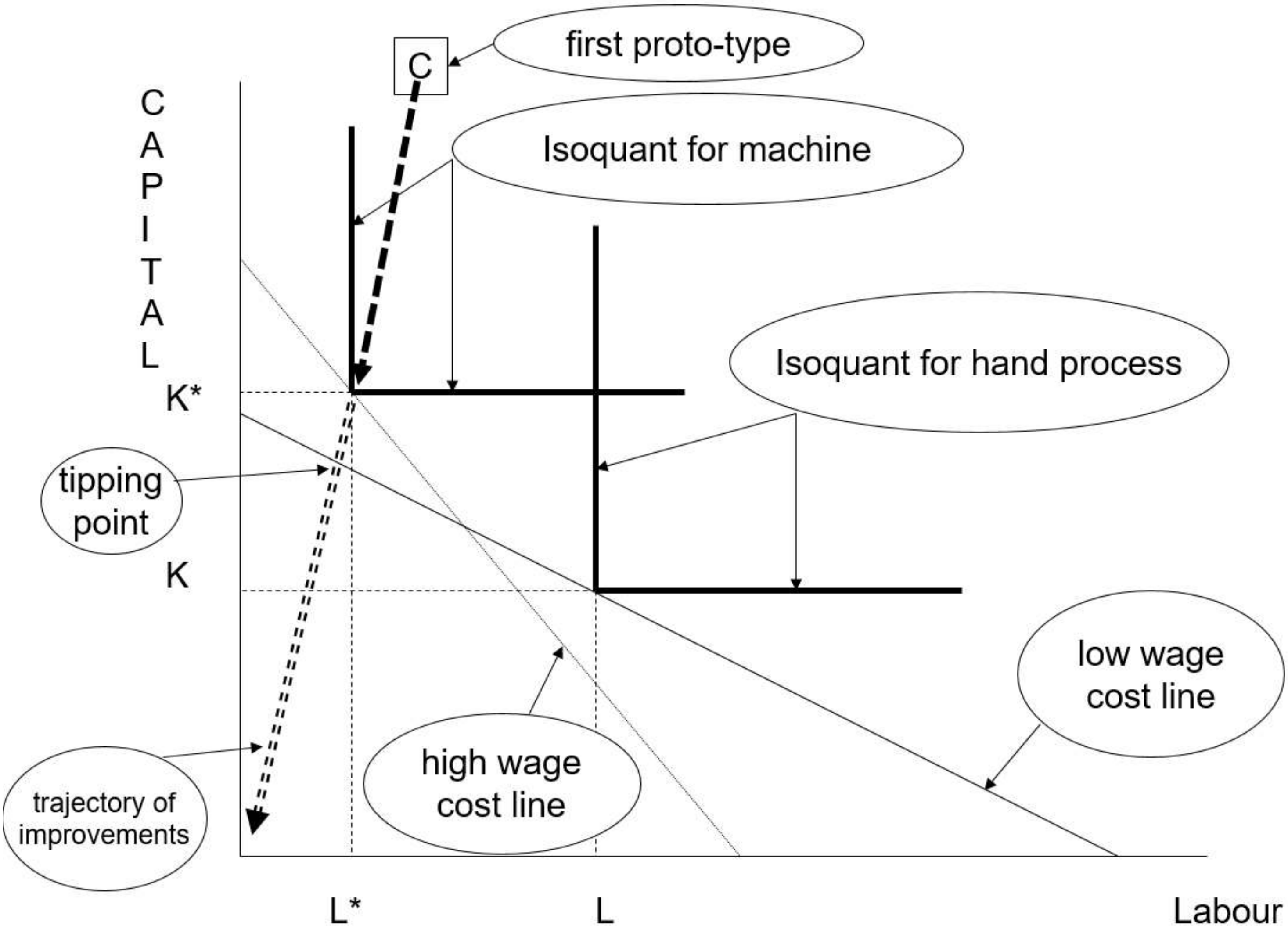
Wages relative to the user cost of capital



Source: Allen (2017, p. 72).

Figure 3

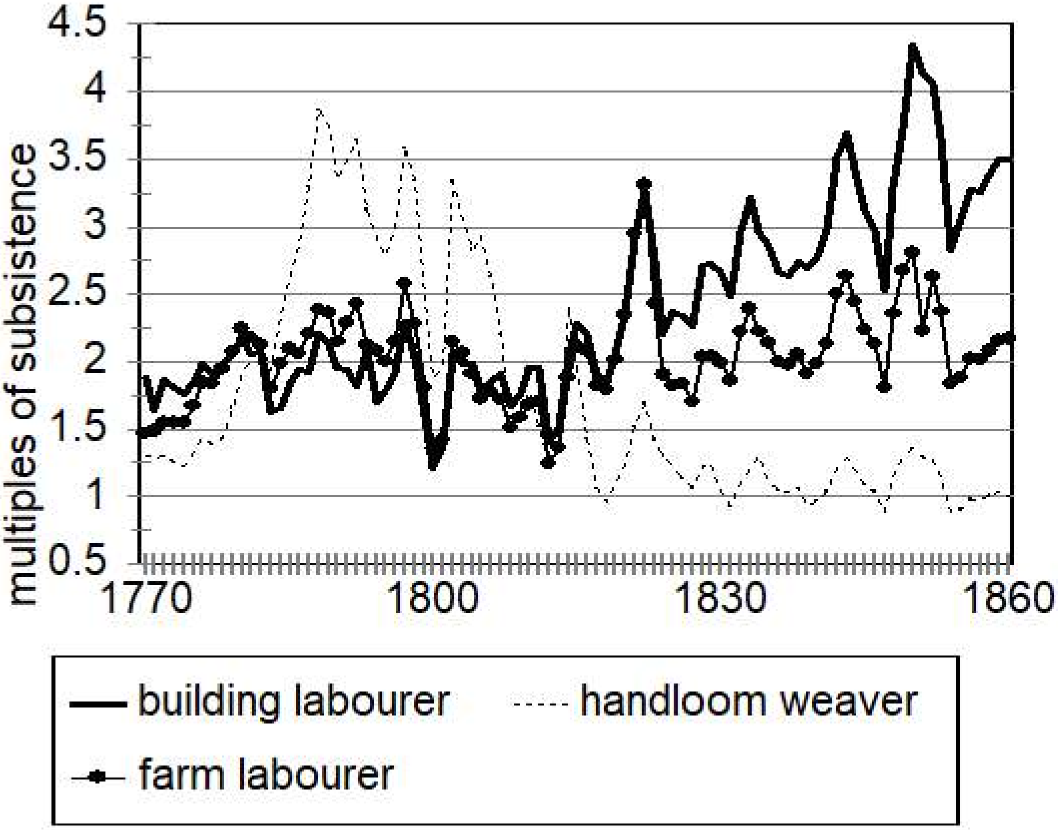
Production model of mechanization



Note: Both isoquants assume the same output level.

Figure 4

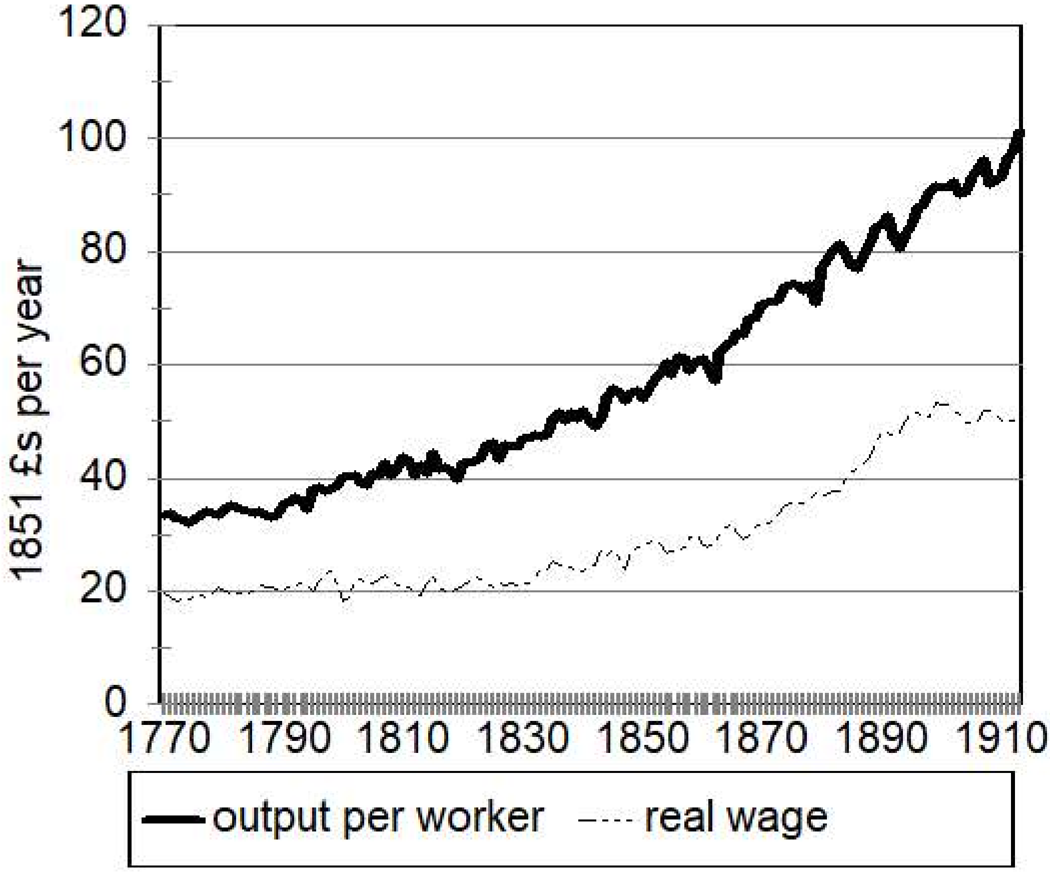
Lancashire Male Labour Market
real earnings, pence per week



Source: Allen (2017, p. 72)

Figure 5

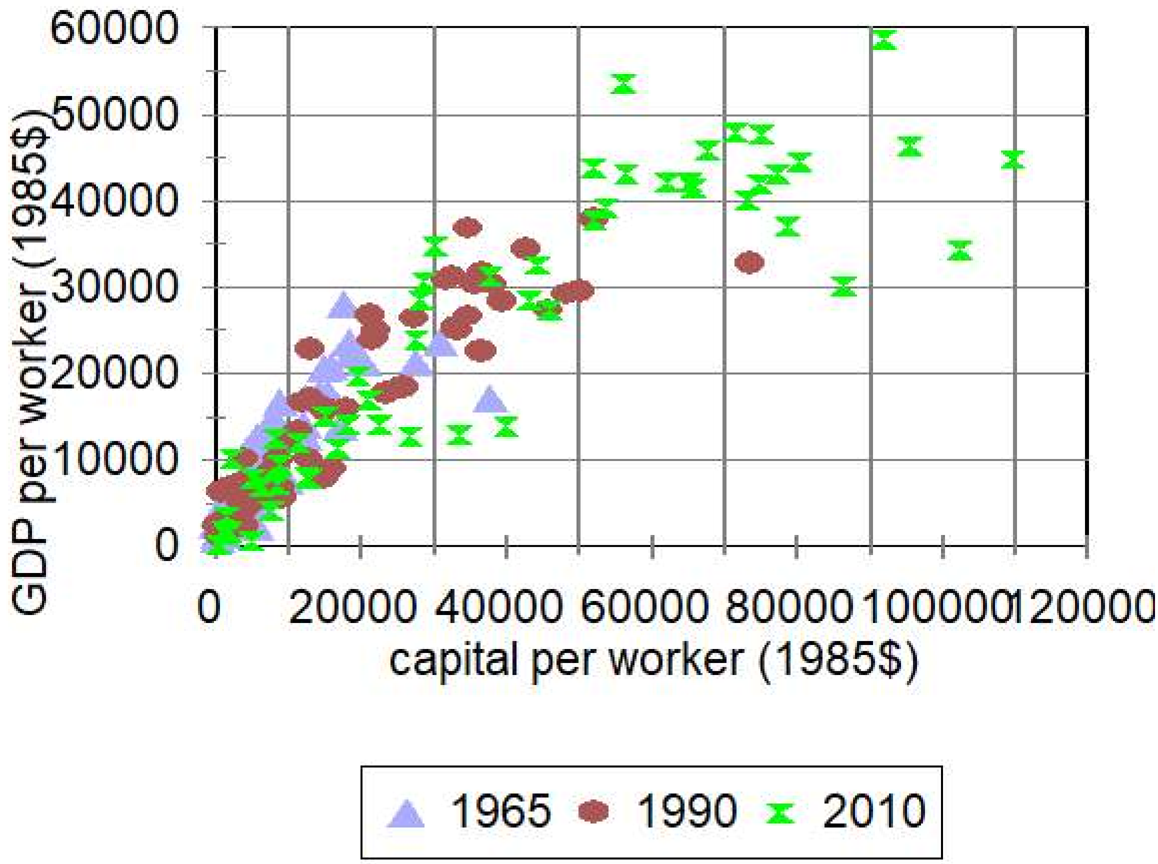
Output per Worker and the Real Wage in Britain



source: Allen (2017, p. 8)

Figure 6

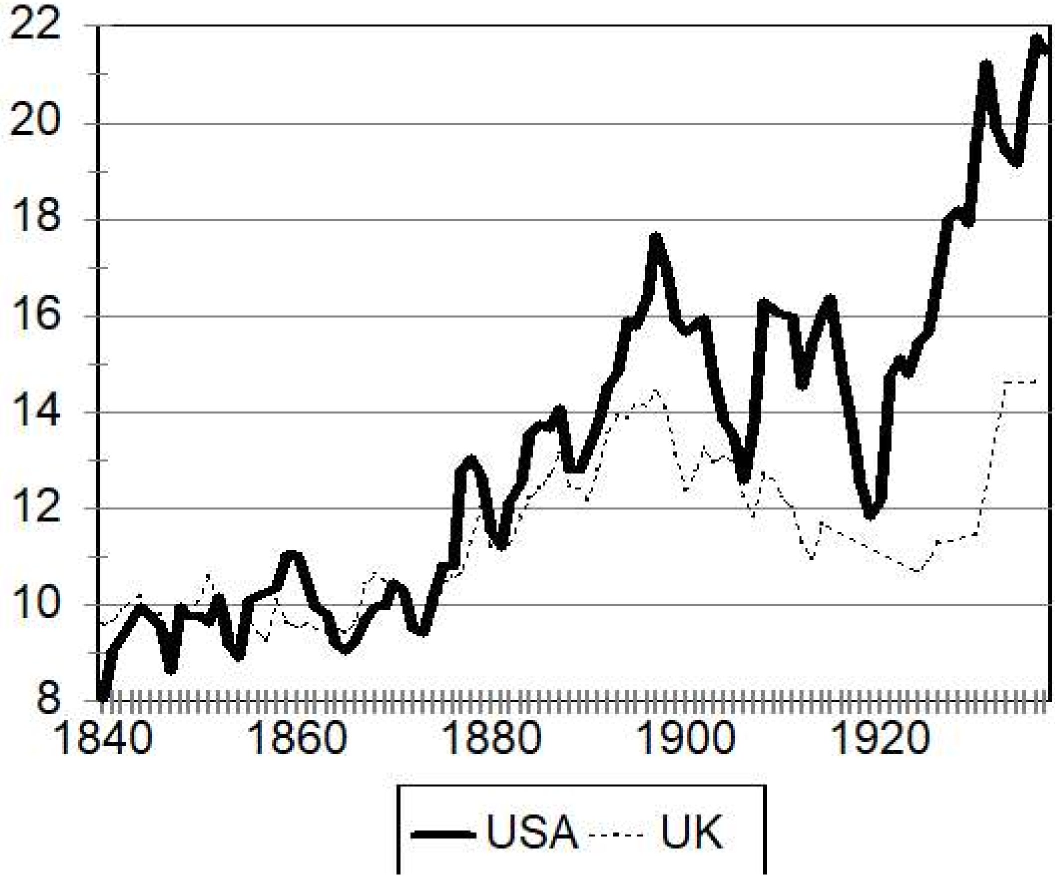
Macro economics of growth, 1965-1990



Source: 1965 and 1990 data from Kumar and Russell (2002) extended to 1995 with Penn World Table, version 9 down loaded from www.ggdc.net/pwt. See Feenstra, Inklar, Timmer (2015).

Figure 7

Unskilled wages relative to user cost of capital



source: nominal wages as described in Figures 11.

user cost of capital–
index equals (interest rate + depreciation rate)*index of cost of capital goods

interest rate:
USA new England municipal bonds, Homer and Sylla (1996, pp. 287-8, 342, 350).
UK yield on long term government bonds, Homer and Sylla (1996, pp. 196-7, 444-5).

depreciation rate: assumed to be 5%

index of cost of capital goods = geometric average of building labour wage rate and arithmetic average of prices of bar iron, copper, soft wood building lumber, and bricks. Sources of prices of bar iron, copper, and lumber have already been given (with the addition that the US bar iron price was extrapolated to 1937 using the price of steel rails).

Bricks–
USA: New York, 1849-1933: U. S. Census Bureau, *Historical Statistics of the United States*, online, Table Cc264.
UK: Glasgow, 1863-1902, United Kingdom, Board of Trade, *Report on Wholesale and Retail Prices in the United Kingdom in 1902, with comparative statistical tables for a series of years,* House of Commons Parliamentary Papers, 1903, Vol. 68, p. 199.

Softwood construction lumber
New York Hemlock–
1890-1920: United States, Department of Labor, Bureau of Labor Statistics (1922. p. 184, Table 9), 'New York Market, average price per M feet'.
1840-1890: extrapolated with Aldrich (1893, Vol. I, p. 46), 'one inch first quality hemlock boards not planed'.
1921-39: extrapolated with Potter and Christy (1962, p. 244, series L).

UK Baltic–
1840-60 extrapolated with *Economist* series of price of Canadian yellow pine from Aldrich (1893, Vol. I, pp. 213-4).
1861-1937 United Kingdom, Board of Trade, *Statistical Abstract for the United Kingdom*, London, HMSO, various years and Sauerbeck (1886, 1907), unit value of imported timber, sawn or split, shillings per load of 50 cubic feet.

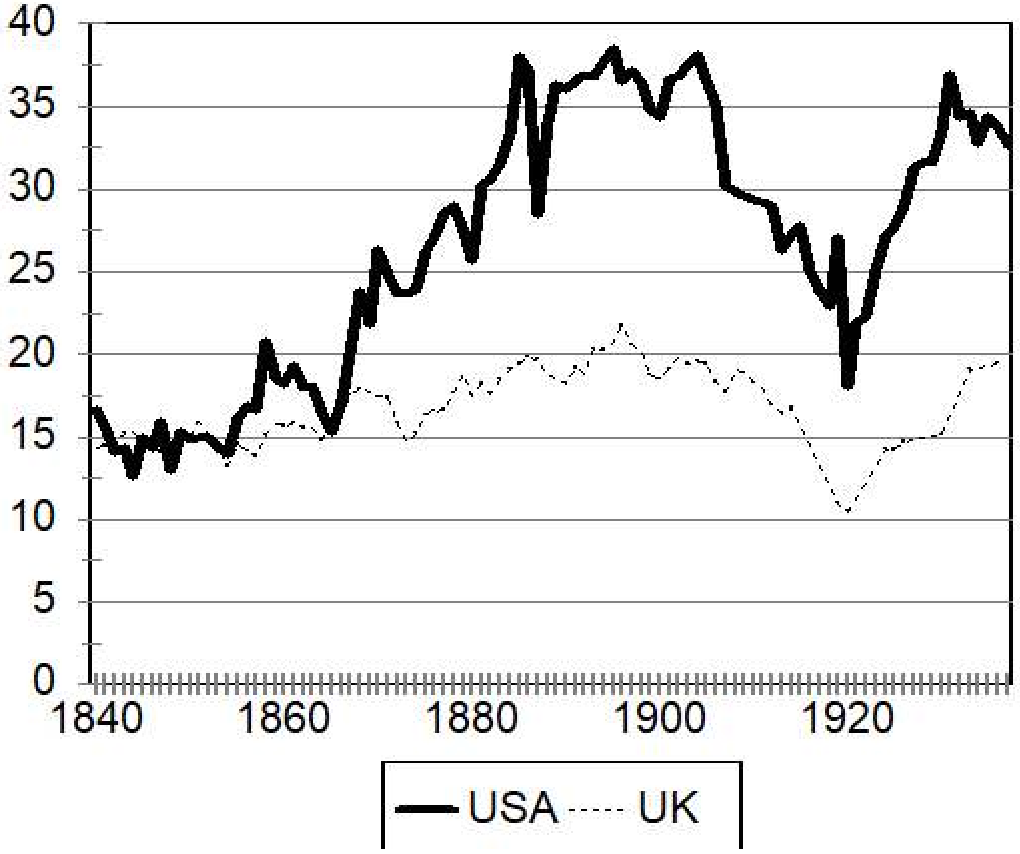
Copper–
USA
1840-1891: Aldrich (1893, Vol. I, p. 40) copper ingots
1892-1939: U. S. Census Bureau, *Historical Statistics of the United States*, online, Table Cc255-Cc257.

Britain
1846-91: Aldrich (1893, Vol.I, p. 234), Saurbeck's prices of copper bars from Chile.
1892-1937: Sauerbeck (1886, 1907), Editor of the Statist (1918, 1938)

Iron–
US bar iron–Philadelphia, best refined bar iron, United States of America, Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, Washington, Government Printing Office, various years. Series extended forward with price of open hearth steel rails in U.S. Census Bureau, *Historical Statistics of the United States*, online, Table Cc245.
UK bar iron–common bars, Mitchell and Deane (1971, pp.493-4).

Figure 8

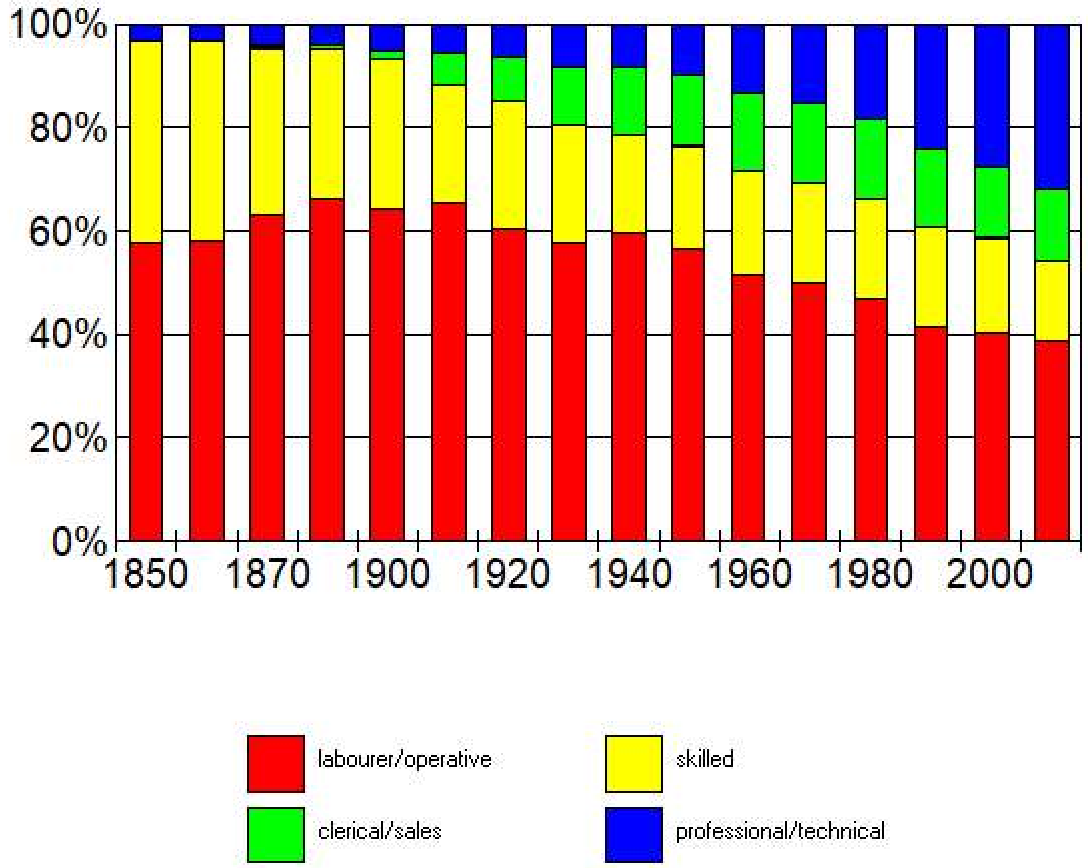
Skilled wages relative to user cost of capital



source: same as Figure 7.

Figure 9

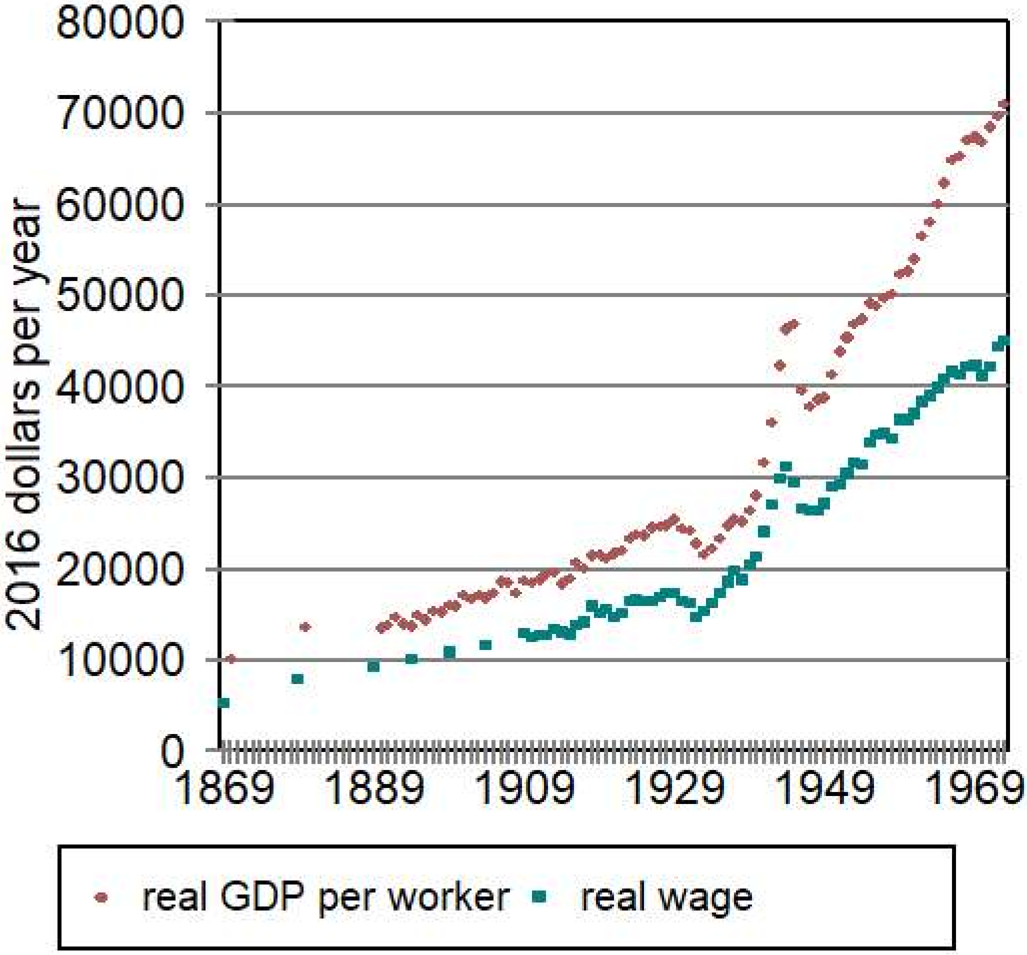
Occupation distribution of U.S.A. manufacturing labour force



Katz and Margo (2014, pp. 37, 45-6).

Figure 10

Real output per worker and average labour income per employed person
in the USA, 1869-1973



note: ‘wage all workers’ includes the self employed. In this graph, their income is set equal to the average wage and salary of all employed workers. Various alternatives were explored and gave similar results.

Sources:
GDP : GDP in billions of chained 2009 dollars from
https://www.bea.gov.national/index.htm#gdp

total workers: 1929-90: total employed civilian labour force, U.S. Census Bureau, *Historical Statistics of the United States*, online, Table Ba471.
1991-2016: Current Population Survey, Labor Force Statistics, series LNS 12000000

total wage and salary income of all employed workers from U.S. Bureau of Economic Analysis, Table 2.1 Personal Income and Its Disposition, 1929-2019, online at https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey

For ‘production and non-supervisory workers,’ total earnings, total number, and earnings per worker’ were computed as--

1909-65: U.S. Census Bureau, *Historical Statistics of the United States*, online, Table Ba4361 and Ba4362. Hourly and Weekly Earnings of Production Workers in Manufacturing, 1909-1965. Hours worked per week calculated as the ratio.

1874-1909: productivity and average wage extrapolated backward from 1909 using Budd (1960, p. 398).

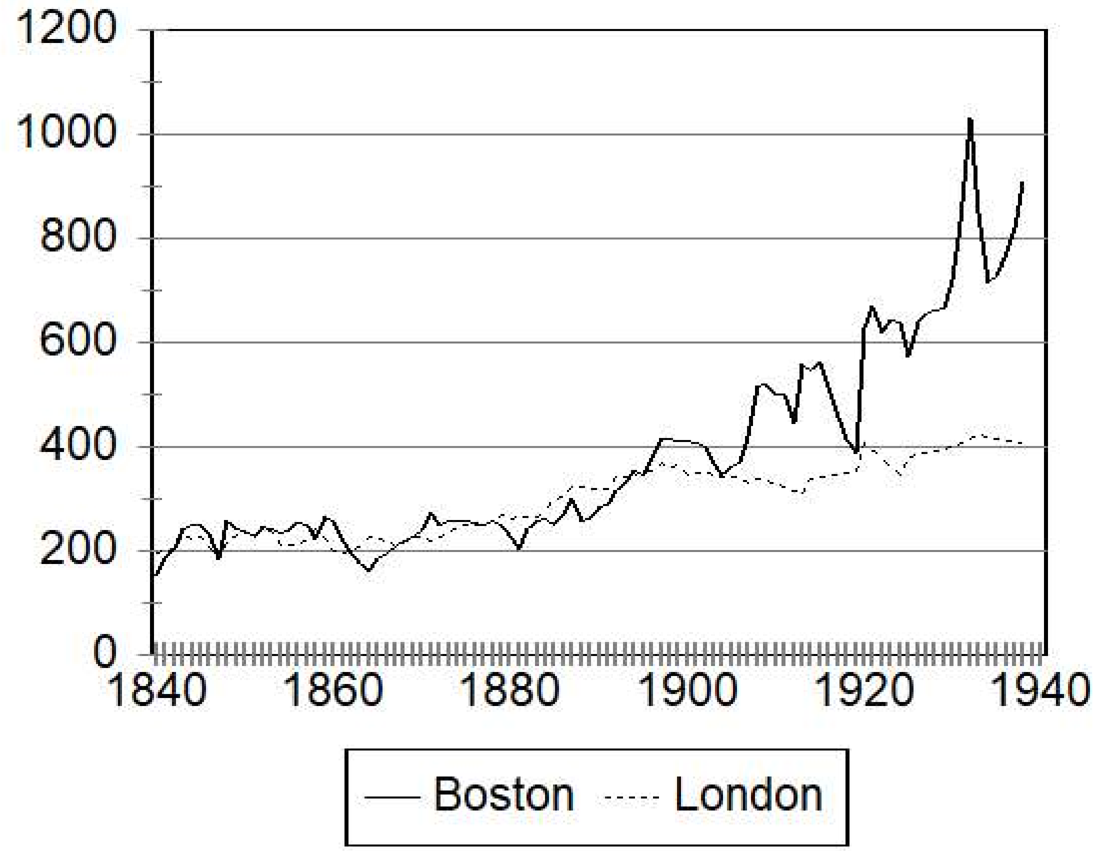
1964-2016: Federal Reserve Bank of St. Louis, FRED economic data, average hourly earnings of production and non-supervisory employees, total private from https://fred.stlouisfed.org/series/CEU0500000008 and total number from Federal Reserve Bank of St. Louis, FRED economic data, production and non-supervisory employees, total private https://fred.stlouisfed.org/series/CES0500000006

total earnings computed as hourly earnings multiplied by 40 hours per week multiplied by number of workers. 40 hours per week is consistent with corresponding data for 1909-65.

For ‘non-production and supervisory’ total earnings, number of workers, and earnings per worker were computed as the totals of all employed workers workers minus the totals for ‘production and non-supervisory workers.’

Figure 11

Unskilled Real Wages in 1905 British pence



sources:
nominal weekly earnings divided by a consumer price index that (in the case of Boston) was converted to sterling using a PPP exchange rate.

Nominal weekly earnings–
Boston–
1840-60: Margo (2000, Table 3A.5, Northeast).
1861-98: BLS 604, pp. 253-60
1900-28: BLS 604, p. 185 (wage per hour multiplied by hours per week).
London–
1840-1860 Schwartz (1985, pp.36-8).
1861-1938 Bowley (1937, pp. 10, 15) and U.K. Department of Employment and Productivity (1971, p. 30, 32). missing values interpolated

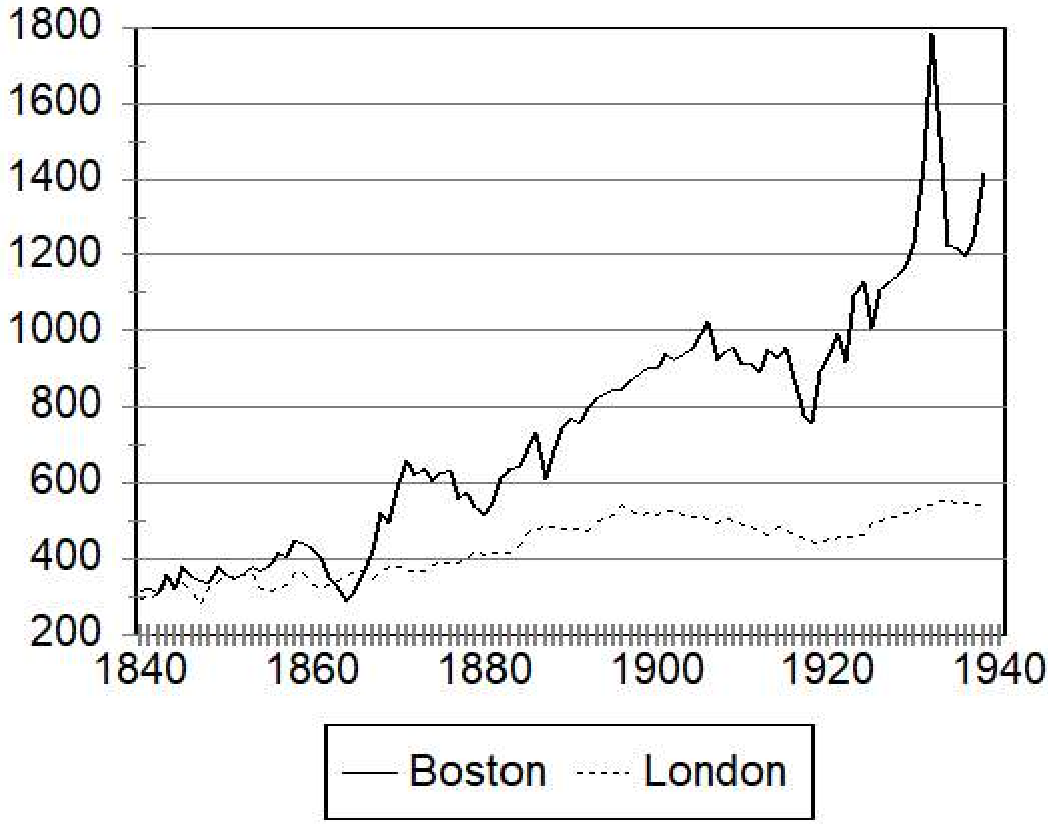
consumer prices indices

USA: Officer and Williamson (2020).
UK: Allen (2007), Feinstein (1998a, pp. 652-3), Feinstein (1972, p. T140), ‘A Millenium of Macroeconomic Data for the UK,’
https://www.bankofengland.co.uk/statistics/research-datasets page A. 47 Wages and Prices, Column BY

PPP exchange rate for 1905. This was constructed using the retail prices of fifteen fuels, coal, kerosene, and house rent in the two countries. Prices and expenditure patterns from U.K. Board of Trade (1911, pp. xxii, xxix-xlvii). Although the USA data were collected in 1909, the Board of Trade concluded that they could be compared to the UK data collected in 1905 without impairing the comparison (p. iii).

Figure 12

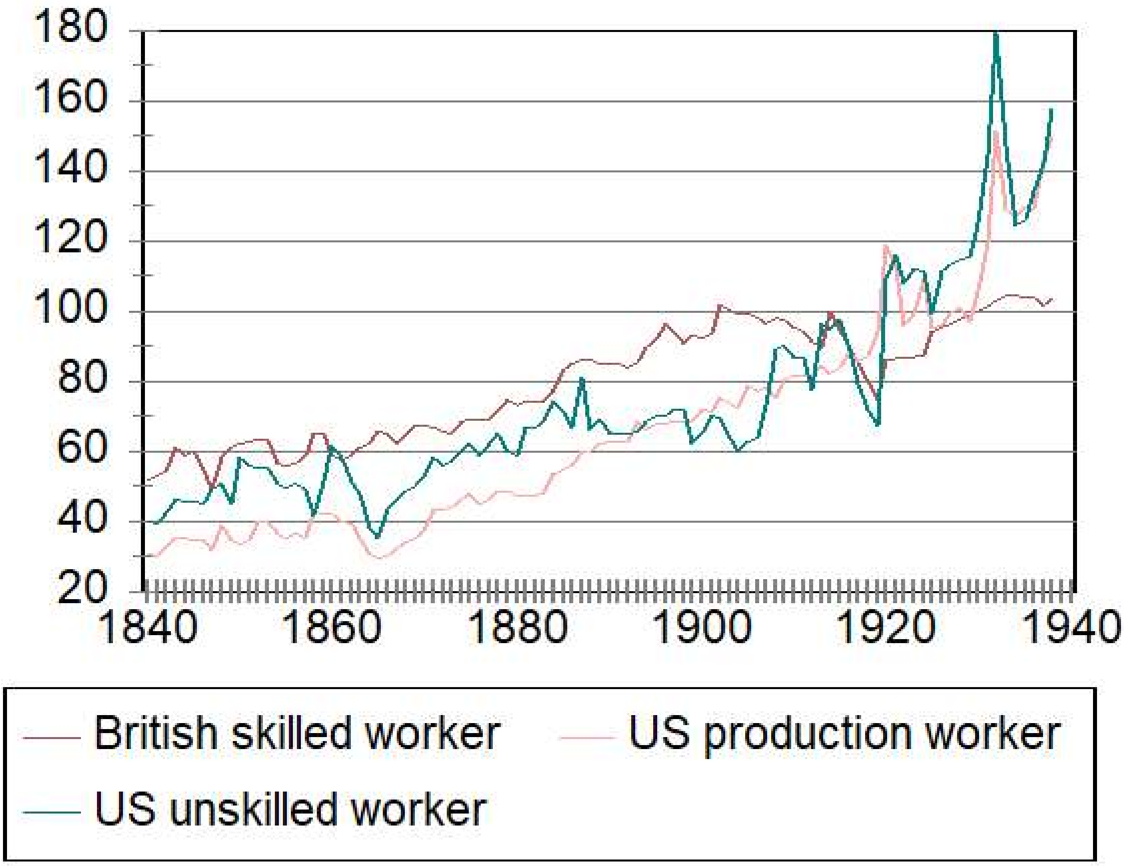
Skilled real wages in 1905 British pence



source: same as Figure 11.

Figure 13

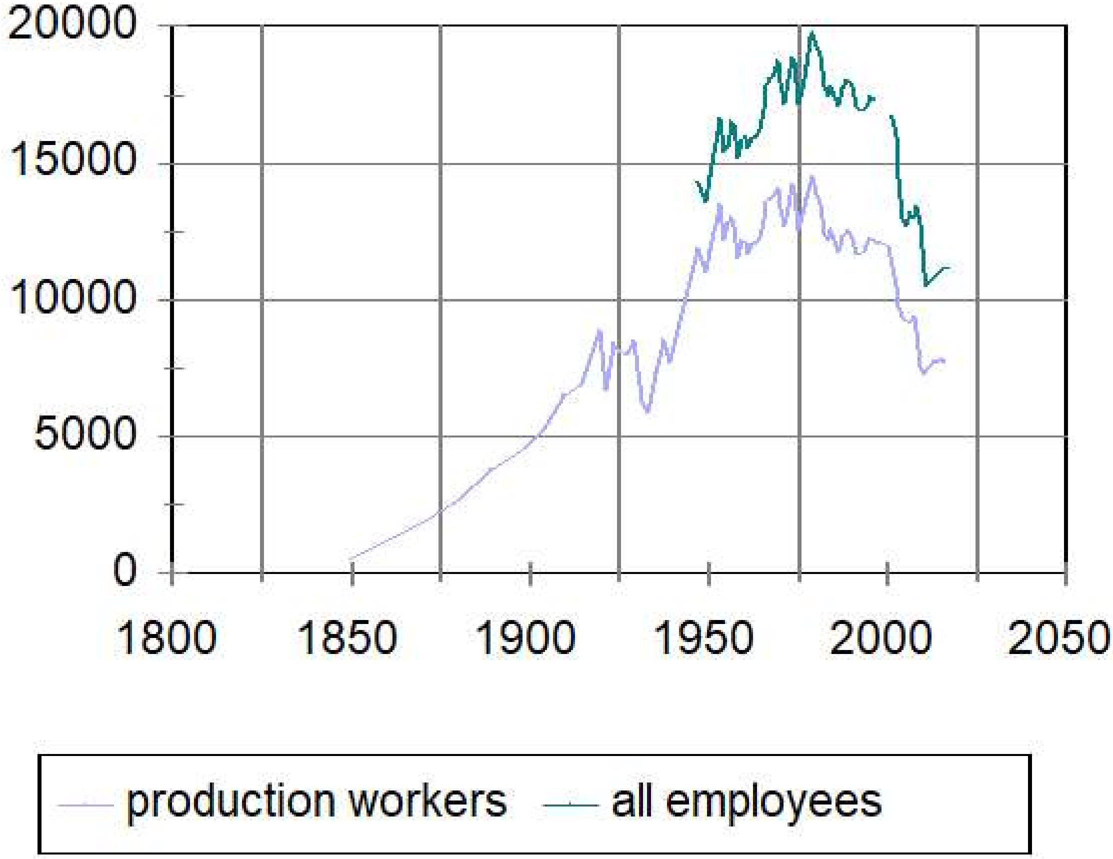
Creation of American 'middle class' (1905 British £s per year)



sources: For nominal wages of British skilled workers, US unskilled workers and for price indices, see sources for Figure 11. For nominal wages of US production workers, see sources for Figure 17.

Figure 14

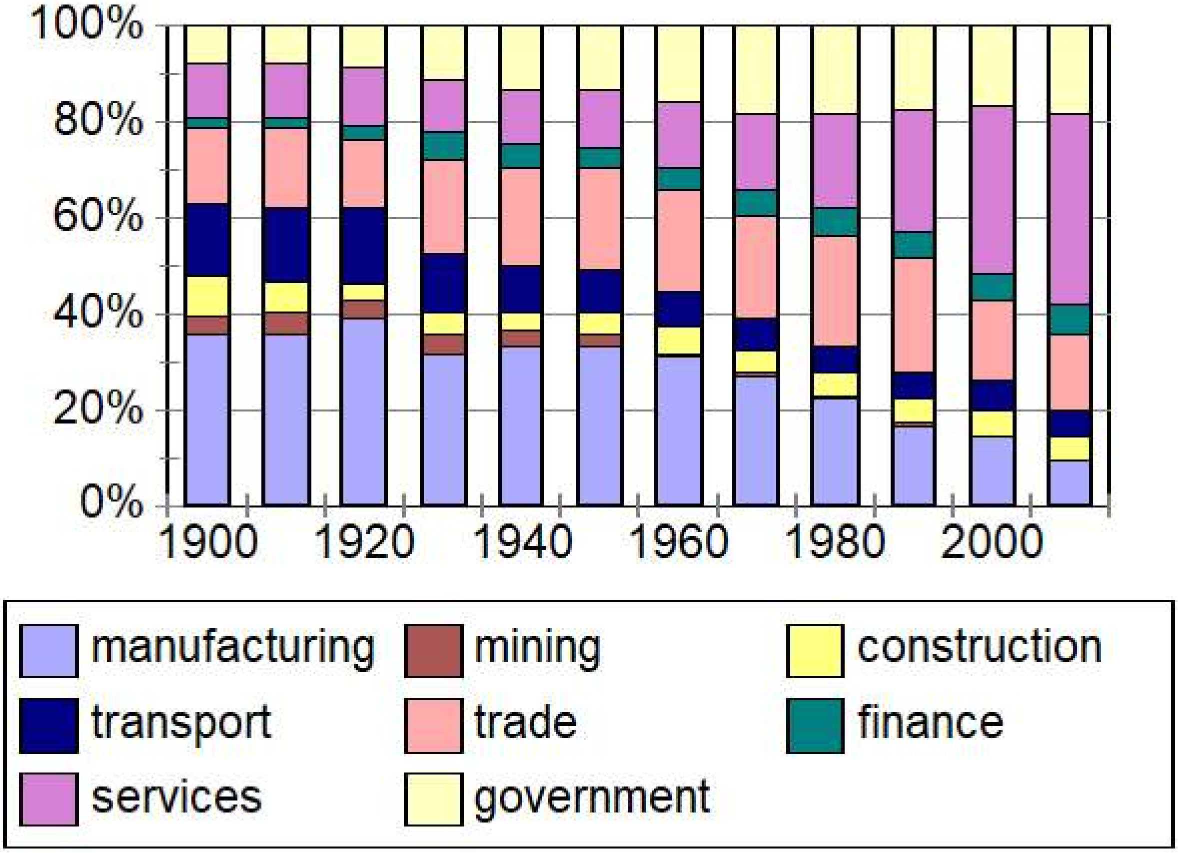
USA employment in manufacturing, 1850-2016



Source:
1850-1999: U.S. Census of Manufactures. The details in the census were retabulated in accord with later definitions.
1899-1999: U. S. Census Bureau, *Historical Statistics of the United States*, online, Table Dd12-231. Manufacturing summary, by industry division–establishments, employment and payroll, value added capital expenditures and aggregate power of equipment: 1899-1999. Many gaps with these data were filled in by reference to the original censuses.
2000-2016: U.S. Census Bureau, *Annual Census of Manufactures*.

Figure 15

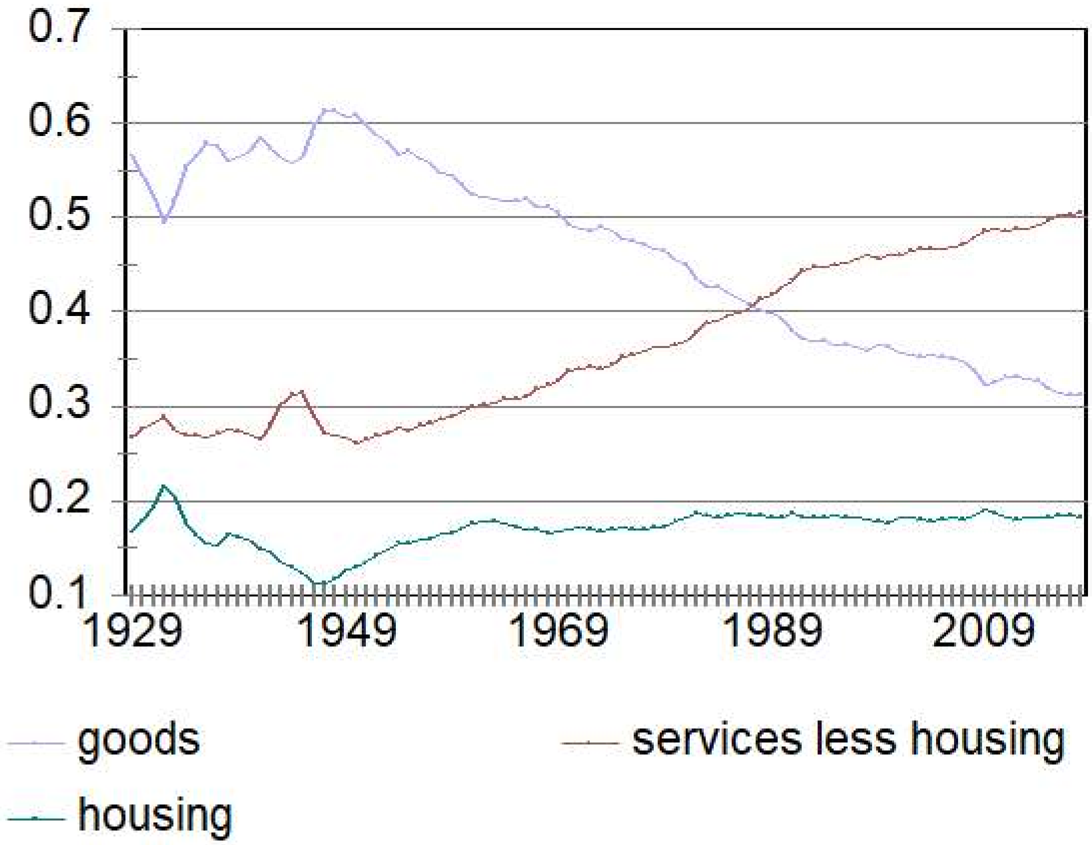
US non-farm employment trends



source: U.S. Census Bureau, *Historical Statistics of the United States*, online, Table Ba840-848, Employees on nonagricultural payrolls, by Industry: 1919-1999 [Bureau of Labor Statistics], extended to 2010.

Figure 16

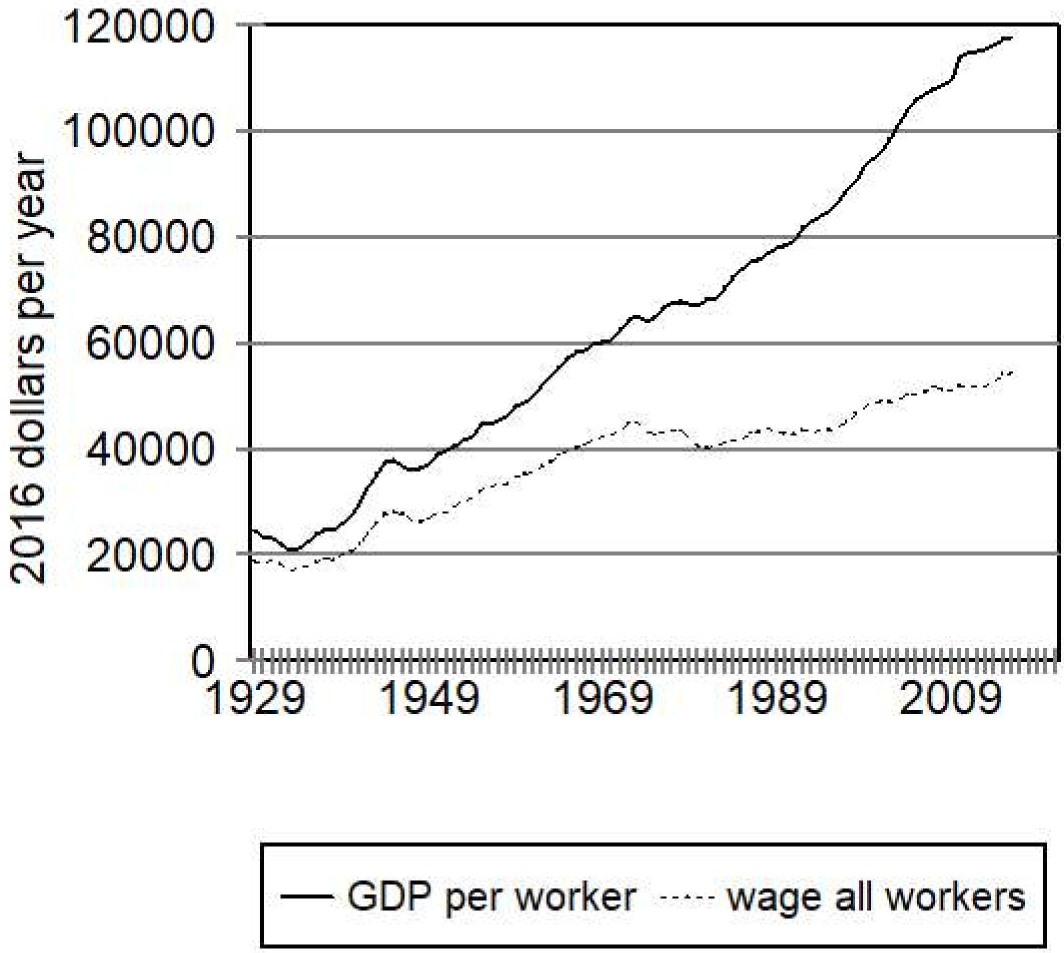
The shift in consumer expenditures from goods to services.



Source: U.S. Bureau of Economic Analysis, Table 2.4.5 Personal Consumption Expenditures by Type of Product, 1929-2019.
https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey

Figure 17

Real output per worker and average labour income per employed person in the USA



note: ‘wage all workers’ includes the self employed. In this graph, their income is set equal to the average wage and salary of all employed workers. Various alternatives were explored and gave similar results.

Sources:
GDP : GDP in billions of chained 2009 dollars from https://www.bea.gov.national/index.htm#gdp

total workers: 1929-90: total employed civilian labour force, U.S. Census Bureau, *Historical Statistics of the United States*, online, Table Ba471.
1991-2016: Current Population Survey, Labor Force Statistics, series LNS 12000000

total wage and salary income of all employed workers from U.S. Bureau of Economic Analysis, Table 2.1 Personal Income and Its Disposition, 1929-2019, online at https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=2&isuri=1&1921=survey

For ‘production and non-supervisory workers,’ total earnings, total number, and earnings per worker’ were computed as--

1909-65: U.S. Census Bureau, *Historical Statistics of the United States*, online, Table Ba4361 and Ba4362. Hourly and Weekly Earnings of Production Workers in Manufacturing, 1909-1965. Hours worked per week calculated as the ratio.

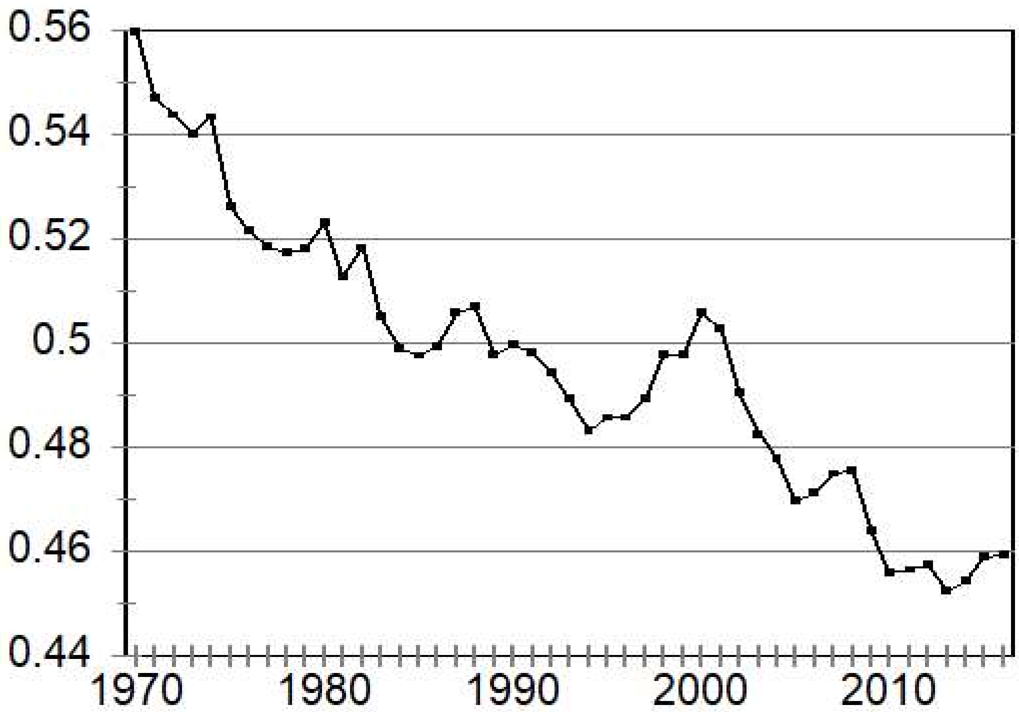
1964-2016: Federal Reserve Bank of St. Louis, FRED economic data, average hourly earnings of production and non-supervisory employees, total private from https://fred.stlouisfed.org/series/CEU0500000008 and total number from Federal Reserve Bank of St. Louis, FRED economic data, production and non-supervisory employees, total private https://fred.stlouisfed.org/series/CES0500000006

total earnings computed as hourly earnings multiplied by 40 hours per week multiplied by number of workers. 40 hours per week is consistent with corresponding data for 1909-65.

For ‘non-production and supervisory’ total earnings, number of workers, and earnings per worker were computed as the totals of all employed workers workers minus the totals for ‘production and non-supervisory workers.’

Figure 18

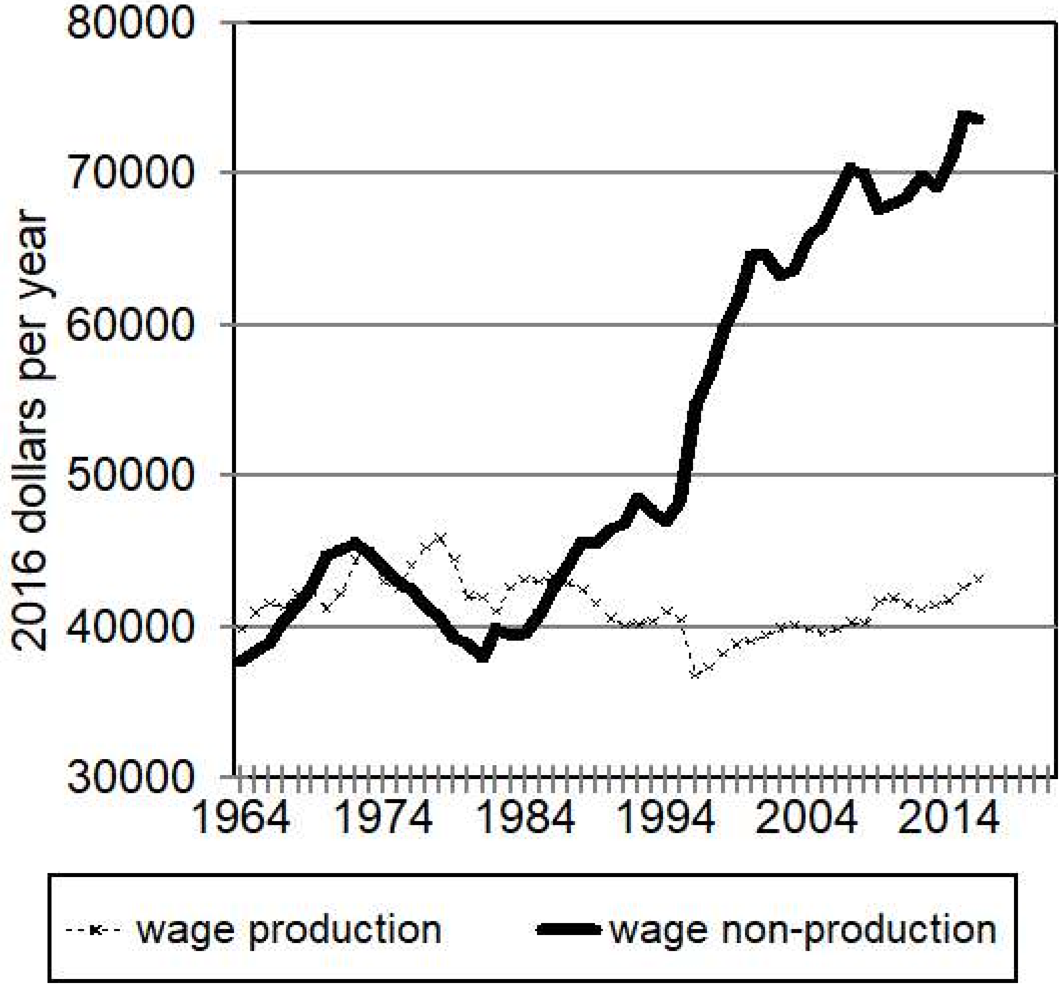
Labour's Share of US GDP



Source: Same as Figure 17.

Figure 19

The wages of production and non-supervisory workers stagnate in USA while the salaries of professional and managerial workers rise



Source: See Figure 17.

<u>References</u>

Acemoglu, Daron (2002), “Directed Technical Change,” *Review of Economic Studies*, Vol. 69, pp. 781–809.

Acemoglu, Daron, David Autor (2011). “Skills, Tasks and Technologies:Implications for Employment and Earnings,” *Handbook of Labor Economics*, Vol. 4b, pp. 1043-1069.

Acemoglu, Daron, David Autor (2012). “What does human capital do? A review of Goldin and Katz’s *The Race between Education and Technology*,” Journal of Economic Literature, Vol. 50, pp. 426-463.

Acemoglu, Daron, David Autor, David Dorn, Gordon H. Hanson, and Brendan Price (2016). “Import Competition and the Great US Employment Sag of the 2000s,” *Journal of Labor Economics*, Vol. 34, No. S1 (Part 2, January 2016), pp. S141-S198

Acemoglu, Daron, Johnson, Simon, and Robinson, James (2005). ‘The Rise of Europe: Atlantic Trade, Institutional Change and Economic Growth,’ *American Economic Review*, Vol. 95, pp. 546-79.

Acemoglu, Daron, and Restrepo, Pascual (2018). “The Race Between Man and Machine: Implications of Technology for Growth, Factor Shares and Employment,” *American Economic Review*, 108(6), pp. 1488–1542.

Acemoglu and Restrepo (2019). “Automation and New Tasks: How Technology Displaces and Reinstates Labor,” *Journal of Economic Perspectives*, 33(2), pp. 3-30.

Acemoglu, Daron, and Robinson, James A. (2015). “The Rise and Decline of General Laws of Capitalism,” *Journal of Economic Perspectives*, Vol. 29, no. 1, Winter, pp. 3-28.

Aghion, P., and P. Howitt. (1992). “A Model of Growth Through Creative Destruction,” *Econometrica*, Vol. 60, pp. 323–351.

Aldrich, Nelson W. (1893). *Wholesale Prices, Wages, and Transportation*, United States Senate. Senate Committee on Finance, 52nd Congress, Washington, Government Printing Office.

Allen, Robert C. (1977). "The Peculiar Productivity History of American Blast Furnaces, 1840-1913," *Journal of Economic History*, Vol. 37, No. 3, September, 1977, pp. 605-633.

Allen, Robert C. (1979). "International Competition in Iron and Steel, 1850-1913," *Journal of Economic History*, Vol. 39, pp. 911-937.

Allen, Robert C. (1981). "Entrepreneurship and Technical Progress in the Northeast Coast Pig Iron Industry, 1850-1913," *Research in Economic History*, Vol. 6, pp. 35-71.

Allen, Robert C. (1983). “Collective Invention,” *Journal of Economic Behavior and Organization*, vol. 4, pp. 1-24.

Allen, Robert C. (2000). “Economic Structure and Agricultural Productivity in Europe, 1300-1800," *European Review of Economic History*, Vol. 3, 2000, pp. 1-25.

Allen, Robert C. (2001). "The Great Divergence in European Wages and Prices from the Middle Ages to the First World War," *Explorations in Economic History*, Vol. 38, October, 2001, pp 411-447.

Allen, Robert C. (2003). “Poverty and Progress in Early Modern Europe,” *Economic History Review*, Vol. LVI, pp. 403-443.

Allen, Robert C. (2007). “Pessimism Preserved: Real Wages in the British Industrial Revolution,” Oxford University, Department of Economics, Working Paper 314. https://www.nuffield.ox.ac.uk/media/2166/allen-pessimism-6.pdf

Allen, Robert C. (2009a). *The British Industrial Revolution in Global Perspective*, Cambridge, Cambridge University Press.

Allen, Robert C. (2009b). “The Industrial Revolution in Miniature: The Spinning Jenny in Britain, France, and India,” *Journal of Economic History*, Vol. 69, No. 4, December, 2009, pp. 901-27.

Allen, Robert C. (2009c). “Engel’s Pause: Technical Change, Capital Accumulation, and Inequality in the British Industrial Revolution,” *Explorations in Economic History*, Vol. 46, Number 4, October, 2009, pp. 418-35.

Allen, Robert C. (2012). “Technology and the Great Divergence: Global Economic Inequality since 1820,” *European Review of Economic History*, 2012, Vol. 40, pp. 1-16.

Allen, Robert C. (2014). “American Exceptionalism as a Problem in Global History,” *Journal of Economic History*, Vol. 74, No. 2, pp. 309-350.

Allen, Robert C. (2015). “The High Wage Economy and the Industrial Revolution: A Restatement,” *Economic History Review*, Vol. 68, No. 1, pp. 1-22.

Allen, Robert C. (2017). *The Industrial Revolution: A Very Short Introduction*, Oxford, Oxford University Press.

Allen, Robert C. (2018). “The Hand-Loom Weaver and the Power Loom: A Schumpeterian Perspective,” *European Review of Economic History*, Vol 22 (4), pp. 381–402

Allen, Robert C. (2019). “Class Structure and Inequality during the Industrial Revolution: Lessons from England’s Social Tables, 1688-1867,” *Economic History Review*, Vol. 72, pp. 88-125.

Allen, Robert C. (2021). "The Interplay among Wages, Technology, and Globalization: The Labour Market and Inequality, 1620-2020," in *Handbook for Historical Economics*, ed. by Alberto Bissin and Giovanni Federico, Amsterdam, Elsevier, Academic Press.

Allen, Robert C., Jean-Paul Bassino, Debin Ma, Christine Moll-Murata, and Jan Luiten van Zanden (2011). "Wages, Prices, and Living Standards in China,1739-1925: in comparison with Europe, Japan, and India," *Economic History Review*, 2011, Vol. 64, pp. 8-38.

Allen, Robert C., Tommy Murphy and Eric Schneider (2012). "The Colonial Origins of Divergence in the Americas: A Labour Market Approach," *Journal of Economic History*, Vol. 72, no. 4, pp. 863-894.

Andersson, R., Quigley, J.M. and Wilhelmsson, M. (2009). "Urbanization, productivity, andinnovation: Evidence from investment in higher education," *Journal of Urban Economics*, Vol. 66, pp. 2–15.

Austrian, Geoffrey (1982). *Herman Hollerith, Forgotten Giant of Information Processing*, New York, Columbia University Press.

Autor, David, David Dorn (2013). "The Growth of Low-Skill Service Jobs and the Polarisation of the US Labor Market," *American Economic Review*, Vol. 103, pp. 1553-1597.

Autor, David, David Dorn, Gordon H. Hanson (2013). "The China Syndrom: Local Labor Market Effects of Import Competition in the United States," *American Economic Review*, Vol. 103, pp 2121-68.

Baines, J.A. (1900). "On Census-Taking and Its Limitations," *Journal of the Royal Statistical Society*, Vol. 63, No. 1, pp. 41-71.

Bowles, Samuel, and Gintis, Herbert (1976). *Schooling in Capitalist America: Educational Reform and the Contradictions of Economic Life*, New York, Basic Books.

Bowley, A. L. (1937). *Wages and income in the United Kingdom since 1860*, Cambridge, Cambridge University Press

Braverman, Harry (1974). *Labor and Monopoly Capital*, New York, Monthly Review Press.

Bright, James R. (1958a). "Does Automation Raise Skill Requirements?" *Harvard Business Review*, pp. 85-98.

Bright, James R. (1958b). *Automation and Management*, Boston, Harvard University.

Broadberry, Stephen N. (1997). *The Productivity Race: British Manufacturing in International Perspective, 1850-1990*, Cambridge, Cambridge University Press.

Broadberry, Stephen and Crafts, Nicholas (2003). "UK Productivity Performance from 1950 to 1979: A Restatement of the Broadberry-Crafts View," *The Economic History Review*, Vol. 56, No. 4, pp. 718-735.

Broadberry, Stephen, and Irwin, Douglas (2006). “Labor productivity in the United States and the United Kingdom during the nineteenth century,” *Explorations in Economic History,* Vol. 43, Issue 2, pp. 257-279.

Broadberry, Stephen, Bruce M.S. Campbell, Alexander Klein, Mark Overton, Bas van Leeuwen (2015). *British Economic Growth: 1270-1870*, Cambridge, Cambridge University Press.

Broadberry, Stephen, and Gupta, Bishnupriya (2009). "Lancashire, India, and Shifting Competitive Advantage in Cotton Textiles, 1700-1850: The Neglected Role of Factor Prices," *Economic History Review,* New Series, Vol. 62, No. 2, pp. 279-305.

Budd, Edward C. (1960). “Factor Shares, 1850-1910,” in *Trends in the American Economy in 1960,* National Bureau of Economic Research, Studies in Income and Wealth, Vol. 24, Princeton, Princeton University Press, pp. 365-406.

Cahan, David (1989). *An Institute for an Empire: The Physikalisch-Technische Reichsanstalt, 1871-1918*, Cambridge, Cambridge University Press.

Case, Anne, and Angus Deaton (2020). *Deaths of Despair and the Future of Capitalism*, Princeton, Princeton University Press.

Chandler, Alfred D. (1977). *The Visible Hand: The Managerial Revolution in American Business*, Cambridge, MA, Belknap Press ofHarvard University Press.

Chinoy, Ely (1955). *Automobile Workers and the American Dream*, Boston, Beacon Press.

Clark, Greg (2005).”The Condition of the Working Class in England, 1209-2004,” *Journal of Political Economy*, Vol. 113, pp. 1307-40.

Clark, Gregory (2007). *A Farewell to Alms: A Brief Economic History of the World*, Princeton, Princeton University Press.

Cohen, H. Floris (2004). “Inside Newcomen’s Fire Engine, or the Scientific Revolution and the Rise of the Modern World,” *History of Technology*, Vol. 25, pp. 111-132.

Collins, William J. (1997). “When the Tide Turned: Immigration and the Delay of the Great Black Migration,” *Journal of Economic History*, Vol. 57, pp. 607-632.

Crafts, N.F.R. (1998). “Forging Ahead and Falling Behind: The Rise and Relative Decline of the First Industrial Nation,” *Journal of Economic Perspectives*, Vol. 12, pp. 193-210.

Crafts, N.F.R. (2004). “Steam as a General Purpose Technology: A Growth Accounting Perspective,” *Economic Journal*, Vol. 114 (495), pp. 338-51.

Crafts, N.F.R. (2012). “British relative economic decline revisited: The role of competition,” *Explorations in Economic History*, Vol. 49, pp. 17-29.

Crafts, N.F.R. (2014). “Economic Growth during the Long Twentieth Century,” in *The Cambridge Economic History of Modern Britain*, ed. By R. Floud, J. Humphries, and P. Johnson, Cambridge, Cambridge University Press, second Edition, *Vol. II: 1870 to the Present*, pp. 26-59.

David, Paul (1975). *Technical Choice, Innovation, and Economic Growth: Essay on American and British Experience in the Nineteenth Century*, Cambridge, Cambridge University Press.

Deane, Phyllis, and Cole, W.A. (1969). *British Economic Growth, 1688-1959*, Cambridge, Cambridge University Press, 2nd edition.

Dehn, R.M.R. (1913). *The German Cotton Industry: A Report*, Manchester, Manchester University Press

Denison, Edward F. (1962). *The Sources of Economic Growth in the United States and the Alternatives Before Us*, New York, Committee for Economic Development, Supplementary Paper No. 13.

Dorn, David, Schmidler, Johannes F., and Spletzer, James R. (2018). Domestic Outsourcing in the United States.

Dreilichman, Mauricio (2005). “The curse of Moctezuma: American silver and the Dutch disease,” *Explorations in Economic History*, Vol. 42, pp. 349-80.

Editor of “The Statist” (1918). “Wholesale Prices of Commodities in 1917,” *Journal of the Royal Statistical Society*, Vol. 81, pp.334-49.

Editor of “The Statist” (1938). “Wholesale Prices in 1937,” *Journal of the Royal Statistical Society*, Vol. 101, pp.376-93.

Egerton, David (2018). *The Rise and Fall of the British Nation: A Twentieth-Centuryh History*, Penguin Random House.

Elbaum, Bernard (1989). “Why Apprenticeship Persisted in Britain But Not in the United States,” *The Journal of Economic History*, Vol. 49, pp. 337-349.

Engels, Frederich (1845). *The Condition of the Working Class in England*, trans. and ed. by W.O. Henderson and W.H. Chaloner, Oxford, Basil Blackwell, 1958.

Feenstra, Robert, Hang Ma, Akira Sasahara, and Yuan Xu (2018). “Reconsidering the ‘China shock’ in trade,” VoxEU 18 January, https://voxeu.org/article/reconsidering-china-shock-trade

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. "The Next Generation of the Penn World Table." *American Economic Review*, 105 (10): 3150-82.

Feinstein, Charles H. (1972). *National Income, Expenditure and Output of the United Kingdom, 1855-1965*, Cambridge, Cambridge University Press.

Feinstein, Charles H. (1998a). "Pessimism Perpetuated: Real Wages and the Standard of Living in Britain during and After the Industrial Revolution," *Journal of Economic History*, Vol. 58, pp.625-658.

Feinstein, Charles H. (1998b). "Wage-Earnings in Great Britain during the Industrial Revolution," in *Applied Economics and Public Policy*, ed. by Iain Begg and S.G.B. Henry, Cambridge, Cambridge University Press, pp. 181-208.

Flood, Sarah, and Miriam King, Renae Rodgers, Steven Ruggles and J. Robert Warren (2020). Integrated Public Use Microdata Series, Current Population Survey: Version 7.0 [ASEC for 1972 and 2017]. Minneapolis, MN: IPUMS, https://doi.org/10.18128/D030.V7.0

Ford, Henry (1922). *My Life and Work*, London, William Heineman.

Friedman, Milton (1962). *Capitalism and Freedom*, Chicago, University of Chicago Press.

Geloso, Vincent (2018). "Were wages that low? Real Wages in the Strasbourg Region before 1775," *Journal of Interdisciplinary History*, Vol. 48, pp. 511-22.

Gilboy, Elizabeth W. (1934). *Wages in Eighteenth Century England*, Cambridge, Harvard University Press.

Goldin, Claudia. (1994). "The Political Economy of Immigration Restriction in the United States, 1890 to 1921." In *The Regulated Economy: A Historical Approach to Political Economy*, ed. by Claudia Goldin and Gary D. Libecap, Chicago, University of Chicago Press, pp. 223-58.

Goldin, Claudia, and Katz, Lawrence (1998). 'The Origins of Technology-Skill Complementarity,' *Quarterly Journal of Economics*, Vol. 113, pp. 693-732.

Goldin, Claudia and Katz, Lawrence (2008). *The race between education and technology*, Cambridge, MA, Belknap.

Goldin, Claudia, and Margo, Robert A. (1992). "The Great Compression: The Wage Structure of the United States at Mid-Century," *The Quarterly Journal of Economics*, Vol. 107, pp. 1-34.

Gordon, Robert J. (2016). *The Rise and Fall of American Growth*, Princeton, Princeton University Press.

Griliches, Zvi (1957). "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, Vol. 25, No. 4, pp. 501-522.

Grossman, Gene M., and Elhanan Helpman (1991). *Innovation and Growth in the Global Economy*, Cambridge, MA, the MIT Press.

Habakkuk, H.J. (1962). *American and British Technology in the Nineteenth Century*, Cambridge, Cambridge University Press.

Hammond, J.L. and Hammond, B (1919). *The Town Labourer: 1760-1832*, London, 4thimpression

Harley, C. Knick (1973). “On the persistence of old techniques: The Case of North American Wooden Shipbuilding,” *Journal of Economic History*, Vol. 33, pp. 372-98.

Harley, C. Knick (1974). "Skilled labour and the choice of technique in Edwardian industry," *Explorations in Economic History*, Vol. 11(4), pp. 391-414.

Hartwell, R. M. (1961). “The Rising Standard of Living in England, 1800-1850,” *Economic History Review*, Vol. 13, No. 3, pp. 397-416.

Hendren, Nathaniel, and Ben Sprung-Keyser (2020). “A Unified Analysis of Government Policies,” *Quarterly Journal of Economics*, Vol. 35, pp. 1209-1318.

Hobsbawm, E.J. (1957). “The British Standard of Living, 1790-1850,” *Economic History Review*, 2nd. ser.,Vol. 10, No. 1, pp. 46-68.

Homer, Sidney, and Sylla, Richard (1996). *A History of Interest Rates*, 3rd ed., rev., New Brunswick, N.J., Rutgers University Press.

Humphries, Jane, and Weisdorf, Jacob (2015). “The Wages of Women in England, 1260–1850,” *The Journal of Economic History*,Vol. 75, pp. 405-447.

Humphries, Jane, and Jacob Weisdorf (2019). “Unreal Wages? Real Income and Economic Growth in England, 1260–1850,” *The Economic Journal*, Volume 129, Issue 623, pp. 2867–2887.

Hyde, Charles K. (1977). *Technological Change and the British Iron Industry, 1700-1870*, Princeton, Princeton University Press.

Jacob, Margaret C. (1997). *Scientific Culture and the Making of the Industrial West*, New York, Oxford University Press.

Jacob, Margaret, and Stewart, Larry (2004). *Practical Matter: Newton’s Science in the Service of Industry and Empire: 1687-1851*, Cambridge, MA, Harvard University Press.

Jones, Charles I. (2005). “The Shape of Production Functions and the Direction of Technical Change,” *Quarterly Journal of Economics*, Vol. 120, Issue 2, pp 517–549.

Jorgenson, Dale, and Z Griliches (1967). “The Explanation of Productivity Change,” *The Review of Economic Studies*, Vol. 34, no. 99, pp. 249-280.

Kaldor, Nicholas (1957). "A Model of Economic Growth," *The Economic Journal*, 67 (268), pp. 591–624.

Katz, Lawrence F., and Krueger, Alan B. (2019). "The Rise and Nature of Alternative Work Arrangements in the United States," *ILR Review* [Internet]. 2019;72 (2) :382-416.

Katz, Lawrence F., and Margo, Robert A. (2014). "Technical Change and the Relative Demand for Skilled Labor: The United States in Historical Perspective," in *Human Capital in History: The American Record*, ed. by Leah Platt Boustan, Carola Frydman, Robert A. Margo, Chicago, University of Chicago Press, pp. 15-57.

Krueger, Alan B. (2018). "Reflections on Dwindling Worker Bargaining Power and Monetary Policy," Jackson Hole Economic Symposium, https://www.kansascityfed.org/~/media/files/publicat/sympos/2018/papersandhandouts/824180824kruegerremarks.ped?la=en.

Krugman, Paul (2016). "Notes on Brexit and the Pound," *The New York Times*, October 11, 2016,.

Kumar, Subodh, and R. Robert Russell (2002). "Technological Change, Technological Catch-up, and Capital Deepening: Relative Contributions to Growth and Convergence ." *American Economic Review*, Vol. 92 (3), pp. 527-548.

Lee, C.H. (1979). *British Regional Employment Statistics, 1841-1971*, Cambridge, Cambridge University Press.

Leunig, Timothy (2003). "A British Industrial Success: Productivity in the Lancashire and New England Industries a Century Ago," *Economic History Review*, Vol. 56, pp. 90-117.

Lindert, Peter H. (2000). "Three Centuries of Inequality in Britain and America," in *Handbook of Income Distribution*, ed. by A.B. Atkinson and F. Bourguignon, Elsevier, pp. 167-216.

Lindert, Peter H. and Williamson, Jeffrey G. (2016). *Unequal Gains: American Growth and Inequality since 1700* , Princeton, Princeton University Press.

Lorenz, E.H. (1991). *Economic Decline in Britain: The Shipbuilding Industry, 1890-1970*, Oxford, Oxford University Press.

Lucas, R.E. (1988) "On the Mechanics of Economic Development," *Journal of Monetary Economics*, Vol. 22, pp. 3-42

Maddison, Angus (2006). *The World Economy*, Paris, OECD.

Margo, R. A. 2000. "New Estimates for Nominal and Real Wages in the Antebellum Period," in *Wages and Labor Markets in the United States 1820–1860*, ed. by Robert A. Margo, Chicago: University of Chicago Press, pp. 36-75.

Margo, Robert A. and Villaflor, Georgia C. (1987). “The Growth of Wages in Antebellum America: New Evidence,” *Journal of Economic History*, Vol. 47, pp. 873-95.

Marx, Karl (1867). *Capital: A Critique of Political Economy*, Moscow, Progress Publishers, First English edition of 1887, Marx/Engels Internet Archive (marxists.org) 1995, 1999, Volume I.

Mazzucato, Mariana (2013). *The Entrepreneurial State*, London, Anthem Press.

Mitchell, Brian R., and Deane, Phyllis (1971). *Abstract of British Historical Statistics*, Cambridge, Cambridge University Press.

Mokyr, Joel (1990). *The Lever of Riches: Technological Creativity and Economic Progress*, New York, Oxford University Press.

Mokyr, Joel (2002). *The Gifts of Athena: Historical Origins of the Knowledge Economy*, Princeton, Princeton University Press.

Mokyr, Joel. (2009). *The Enlightened Economy: The Economic History of Britain, 1700-1850*, Penguin Press.

Mokyr, Joel. (2017). *The Culture of Growth*, Princeton, Princeton University Press.

Nelson, Richard R, and Gavin Wright (1992). “The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective,” *Journal of Economic Perspectives*, Vol. 30, pp. 1931-1964.

North, Douglas C., and Robert Paul Thomas (1973). *The Rise of the Western World*, Cambridge, Cambridge University Press.

Nuvolari, Alessandro (2004). “Collective Invention during the British Industrial Revolution: the Cast of the Cornish Pumping Engine,” *Cambridge Journal of Economics*, vol. 28, pp. 347-63.

Officer, Lawrence H.and Samuel H. Williamson, (2020). "The Annual Consumer Price Index for the United States, 1774-Present," MeasuringWorth, URL:http://www.measuringworth.com/uscpi/

O'Rourke, K. H. (1997). “The European grain invasion, 1870-1913,” *Journal of Economic History*, Vol. 57(4), pp. 775-801.

O'Rourke, Kevin H.(2019). “Economic History and Contemporary Challenges to Globalization,” *Journal of Economic History*, Vol. 79, pp. 356-382.

O'Rourke, Kevin H. and Williamson, Jeffrey G. (1999). *Globalization and history: the evolution of a nineteenth-century Atlantic economy*, Cambridge, MA, MIT Press.

Piketty, Thomas (2014). *Capital in the Twenty-First Century*, Cambridge, MA, Harvard University Press.

Potter, N., and Christy, Jr,.Francis T. (1962). *Trends in Natural Resource Commodities: Statistics of Prices, Output, Consumption, Foreign Trade, and Employment in the United States, 1870-1957*, Resources for the Future, Baltimore, The Johns Hopkins Press.

Pierce, Justin R., and Shott, Peter K. (2016). “The Surprisingly Swift Decline of US Manufacturing Employment,” *American Economic Review*, Vol. 106(7), pp 1632–1662.

Piketty, Thomas (2014). *Capital in the Twenty-First Century*, Cambridge, MA, Harvard University Press.

Pribram, A.F. (1938). *Materialen zue Geschichte der Preise und Löhne in Österreich*, Band I, Vienna, Carl Ueberreuters Verlag.

Ray, Debraj (2015). "Nit-Piketty: A Comment on Thomas Piketty’s Capital in the Twenty First Century," CESifo Forum, ifo Institute - Leibniz Institute for Economic Research at the University of Munich, Vol. 16(01), pp. 19-25.

Romer, Paul M. (1986). “Increasing Returns and Long-Run Growth,” *Journal of Political Economy*, Vol. 94, pp. 1002-1037.

Romer, Paul M. (1990). “Endogenous Technical Change,” *Journal of Political Economy*, Vol. 98, pp. S71-S102.

Sauerbeck, Augustus (1886). “Prices of Commodities and the Precious Metals,” *Journal of the Statistical Society of London*, Vol. 49, No. 3, pp. 581-648.

Sauerbeck, Augustus (1907). “Prices of Commodities in 1906,” *Journal of the Royal Statistical Society*, Vol. 70, pp. 107-21.

Schumpeter, Joseph A. (1994). *Capitalism, Socialism, and Democracy*, London, Routledge, ebook.

Solow, Robert M. (1956). “A Contribution to the Theory of Economic Growth,” *The Quarterly Journal of Economics*, Volume 70, Issue 1, pp. 65–94.

Summers, Robert, and Heston, Alan (1984). “Improved International Comparisons of Real Product and its Composition: 1950-1980,” *Review of Income and Wealth*, Vol. 30, No. 2, pp. 207-62.

Taylor, Frederick W. (1911). *The Principles of Scientific Management*, New York, Harper & Brothers.

Temin, Peter (1964). *Iron and Steel in Nineteenth-century America: An Economic Enquiry*, Cambridge, MA, The MIT Press.

Temin, Peter (2017). *The Vanishing Middle Class: Prejudice and Power in a Dual Economy*, Cambridge, MA, The MIT Press.

Truesdell, Leon E. (1965). *The Development of Punch Card Tabulation in the Bureau of the Census, 1890-1940*, Washington, Bureau of the Census.

U.K. Department of Employment and Productivity (1971). *British Labour Statistics: Historical Abstract*, *1886-1968*, London, Her Majesty's Stationery Office.

Voth, Joachim (2020). "Fighting for Growth: Labor Shortages and Directed Technical Change during the British Industrial Revolution," xx

Williamson, Jeffrey G. (1995). "The Evolution of Global Labor Markets since 1830: Background Evidence and Hypotheses," *Explorations in Economic History*, Vol. 32, pp. 141-96.

Williamson, Jeffrey G., and Lindert, Peter H. (1980). *American Inequality: A Macroeconomic History*, New York, Academic Press.

Wrigley, E.A. and Schofield, R.S. (1981). *The Population History of England, 1541-1871*, London, Edward Arnold.