



Skilling and deskilling: technological change in classical economic theory and its empirical evidence

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Abstract

This article reviews and brings together two literatures: classical political economists' views on the skilling or deskilling nature of technological change in England, during the eighteenth and nineteenth centuries when they wrote, are compared with the empirical evidence about the skill effects of technological change that emerges from studies of economic historians. In both literatures, we look at both the skill impacts of technological change and at the “inducement mechanisms” that are envisaged for the introduction of new technologies. Adam Smith and Karl Marx both regarded the deskilling of the labour force as the predominant form of biased technical change, but other authors such as Charles Babbage also took account of capital-skill complementarities and skill-enhancing effects of technological change. For Smith, the deskilling bias was an unintended by-product of the increasing division of labour, which in his view “naturally” led to ever more simplification of workers' tasks. As opposed to Smith, Marx considered unskilled-biased technical change as a bourgeois weapon in the class struggle for impairing the workers' bargaining position. Studies of economic historians lend support to Marx's hypothesis about the inducement mechanisms for the introduction of unskilled-biased innovations, but have produced no clear-cut empirical evidence for a deskilling tendency of eighteenth- and nineteenth-century technological change as a whole. Industrialization in the eighteenth and nineteenth centuries rather led to labour polarization, by simultaneously deskilling a large part of the workforce and raising the demand for some (but fewer) high-skilled workers.

Keywords Adam Smith · Capital-skilled labour complementarities · Induced technical change · Karl Marx · Polarization · Skill-biased technical change

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Technical change and its effects on wealth, consumption, employment, and income distribution were key themes in the writings of the classical economic theorists. Adam Smith's discussion of the causes and effects of the increasing division of labour was followed by the compensation debates between Say, Malthus, Sismondi, and McCulloch, until Ricardo and Marx opened, with their contributions on the machinery problem, one of the longest and most intensive debates in the history of economic theory. But in most of these studies an analytical framework with homogenous labour was employed for the sake of simplicity—this holds in particular for the contributions of Ricardo and Marx on the effects of the introduction of machinery on the conditions of the working class.

However, the classical economists were aware of the fact that labour displacement and compensation are not the only important aspects of the impact of technical change on the conditions of workers. Even if innovations do not lead to mass unemployment, they nevertheless change employments dramatically—in terms of working conditions, demands for professional skills, bargaining positions, etc. In the works of Adam Smith, John R. McCulloch, Jean-Baptiste Say, Andrew Ure, Charles Babbage, and Karl Marx we find at least some hints on how, when, and why technical change is likely to increase, diminish, or shift the demand for skilled and unskilled labour. It is perhaps because classical economics is so closely associated with the labour theory of value that classical contributions on heterogeneous labour, such as skill-biased or unskilled-biased technical change, are almost forgotten.

The purpose of this article is to review the views of the classical economists on biased technical change and its induction and to contrast these views with the available empirical evidence. Accordingly, we first provide a summary account of the ideas of major classical economists on the skill effects of technological changes and then investigate the empirical evidence for different theoretical views on the skilling and deskilling character of eighteenth- and nineteenth-century technological change. We show that the widely shared view—among both classical economists and some modern growth theorists—that prior to the twentieth century technical change was predominantly deskilling, is *not* confirmed by empirical data. In addition, we also discuss the classical economists' views about possible “inducement mechanisms” that might have led to technological changes with a particular bias. We then also outline what the recent growth theory literature on biased technological change, in which it is generally assumed that the innovation bias is induced by (changing) relative factor endowments with skilled and unskilled labour (see, in particular, Acemoglu 1998), might be able to “learn” from the classical political economists.

As we shall see, the general presumption of classical political economists that the early stages of industrial capitalism were characterized by a clear deskilling trend is not well supported by empirical evidence, which is much more mixed. What, then, prevented the classical economists from correctly assessing the direction of skill change? In our view, this question necessitates different answers for different authors. Adam Smith, who witnessed only the beginning of the Industrial revolution in the mid-eighteenth century, related technological change to the increasing *division of labour* that “naturally” accompanied the economic development of capitalist societies. For him, a greater division of labour must inevitably be associated with a simplification of the tasks to be performed by each individual worker. He thus simply projected observations from his own immediate experience into future technological

developments. Karl Marx, on the other hand, was writing in the third quarter of the nineteenth century, when the manufacturing system had already given way to the emergence of “modern industry” in England. In his case, the presumption of a deskilling bias derived from his narrow “class struggle view” of the induction of technological change: innovations, he argued, were deliberately aimed at simplifying the workers’ tasks in order to enable the replacement of skilled workers by unskilled ones. He simply could not imagine that capitalists would intentionally introduce skill-enhancing technologies and thereby impair their own bargaining position in the class struggle.

The classical economists’ contributions to biased technological change

In the context of the so-called “new growth theory” there has been a renaissance of economic discussions on biased technological change. Many recent studies deal with the question whether increasing wage premiums for skilled workers can be explained by skill-biased technological change (see Brugger and Gehrke 2017). The argument is that an increasing supply of skilled labour has induced profit-maximizing capital goods producers to search more intensively for new technologies that are complementary to skilled labour. Due to the more widespread use of skilled-labour complementary capital goods, the relative demand for skilled labour increased and therefore the skill premium rose. Hence skill-biased technical change functions as a possible explanation for the conundrum that skill supply and skill premiums increased in tandem.

While these studies mainly focus on technological change in the twentieth and twenty first centuries, it is suggested in many of those contributions (Acemoglu 1998, 2002, 2009; Goldin and Katz 1998; Funk and Vogel 2004) that in the nineteenth century technical change was predominantly deskilling, but that things have changed since then. “Stories” on how the shift from small-scale artisanal production to large-scale factory production led to the replacement of high-skilled artisans by unskilled factory workers, frequently women and children, are the main source of evidence for the presumption that in the nineteenth century technical change must have been deskilling in nature. However, gut-wrenching stories about nineteenth-century working conditions are helpful to understand the inhumane and dreadful conditions under which large parts of the population had to work and live, but may be bad guides for ascertaining the technical change bias. And also accounts based on “realistic stories” of contemporary fiction writers such as Thomas Carlyle, Charles Dickens, William Morris, and John Ruskin, the existence of highly visible losers and hidden winners (Manning 2004), and the reliance on *indirect* empirical evidence based on “indicators” and “approximations” (Bessen 2011), may give a misleading picture of the nineteenth-century technical change bias.

Economic historians, apart from providing historical accounts of technological changes during the Industrial Revolution, have also recently begun using quantitative data to estimate the technological change bias. Employing various indicators for biased technological change and exploring a host of different data sources, recent empirical studies attempt to account for the quantitative effects of industrialization on the demand for skilled and unskilled labour.

In modern growth theory, skill-biased technical change is defined as a shift in the production function that favors skilled over unskilled labour: It is a non-neutral technological change that increases the relative marginal productivity, and therefore also the relative wage, of skilled labour. Accordingly, an increase in the relative wage of skilled labour, that is, an increase in the so-called “college premium” (or “skill premium”), can *ceteris paribus* serve as an indicator of skill-biased technical change. Empirically, skill-biased technical change is usually measured residually by assuming an aggregate production function with capital (K) and labour (L) as inputs, in which the labour input, L , is specified as a constant elasticity of substitution (CES) function of skilled and unskilled labour with factor-specific productivities. From time series data on relative wages and on relative factor supplies, this modified Solovian production function can then be used, with a given estimate of the elasticity of substitution between the two types of labour, to calculate the skill-biased technical change measure (Violante 2008).

In the modern approach, the distinction between “skilled” and “unskilled labour” is typically based on differences in “years of schooling and higher education.”¹ Adam Smith’s use of these terms in the *Wealth of Nations* (1976 [1776]; *WN* hereafter) is partly, but not fully in line with the modern usage. Smith generally employs the term “common labour” for unskilled labour, that is, for labour that can be performed without first acquiring specific skills by way of education or professional training, apprenticeship, or learning-by-doing. As regards Smith’s concept of “skilled labour,” he saw two different types of learning or ways of acquiring skills to be involved: (formal) education and experience, i.e., “learning-by-doing.” Smith drew a strict analogy between an item of fixed physical capital (“a machine”) and skilled labour power, and thus he can be said to have anticipated the concept of “human capital.”²

When any expensive machine is erected, the extraordinary work performed by it before it is worn out, it must be expected, will replace the capital laid out upon it, with at least the ordinary profits. A man educated at the expence of much labour and time to any of those employments which require extraordinary dexterity and skill, may be compared to one of those expensive machines. The work which he learns to perform, it must be expected, over and above the usual wages of common labour, will replace to him the whole expence of his education, with at least the ordinary profits of an equally valuable capital. It must do this too in a reasonable time, regard being had to the very uncertain duration of human life, in the same manner as to the more certain duration of the machine. (*WN*, I.x.b.6)

Smith claimed that “the difference between the wages of skilled labour and those of common labour, is founded upon this principle” (*WN*, I.x.b.7). For Smith, a wage premium for skilled labour is thus a compensation for expenses incurred in the formation of “human capital”. However, Smith also recognized that some of these expenses are not incurred by individuals, but rather by the public at large, and that

¹ However, for measuring skill-biased technical change by employing the (appropriately modified) Solovian production function approach “it is not necessary to specify what makes a worker more skilled than another: it could be education, innate ability or experience” (Violante 2008, p. 8).

² See Spengler (1977) and Kurz and Salvadori (1995, pp. 327–331).

“human capital” is not merely a private capital, but also forms part of society’s capital stock; compare Smith’s treatment of the acquired skills of a population as a part of the nation’s capital stock in Chapter 1 of Book II of the *WN*, where he emphasizes the public good character of a better educated workforce.

Reading classical economists’ contributions on skill-enhancing and deskilling technological change, one can easily obtain the image that technical change was heavily deskilling in the eighteenth and nineteenth centuries. In particular, major representatives of classical economics like Adam Smith and Karl Marx appear to have been strong advocates of the deskilling technological change hypothesis. They prominently argued that industrialization and mechanisation caused a strong deskilling tendency, in the sense that the duties formerly conducted by craftsmen got reduced to a few simple and recurrent operations, which allowed skilled artisans to be replaced by unskilled women and children. Given these views of prominent classical economists, it is not surprising that recent contributions follow their assessment in suggesting that before the twentieth century technical change was deskilling in nature. Nevertheless, already in the nineteenth century we find contemporary authors who were much more optimistic with regard to the impact of technological change on the demand for skilled labour. For example, Charles Babbage considered new techniques to have been often more skilled-labour-intensive than the replaced ones. Therefore the relationships among industrialization, mechanisation, and skilled labour demand are not as straightforward as they may appear at first sight. The empirical evidence on the bias of technological change in the eighteenth and nineteenth centuries is in fact rather mixed, as we shall see below.

The pessimistic view: Adam Smith

According to Adam Smith, technical change increases (labour) productivity, real wages, and employment, and it decreases prices, and therefore widens the extent of the market and raises wealth and prosperity. Hence, for Smith technical change is a success story close to Pareto superiority, were it not for a strong unskilled labour bias. Smith is rather optimistic that discharged craftsmen will more or less “immediately” find new employment or may even continue in their former occupation and see only their tasks changed. However, whereas in their former jobs the craftsmen had to command and perform various skills, the new jobs often consist only of a few simple and repetitive operations.

For Smith, technical change, which he identified with “increasing division of labour,” is generally associated with both skill-reducing and skill-enhancing tendencies, at least in the early stages of the industrialization process. On the one hand, Smith emphasized, in his famous chapter the “Causes of Improvement in the productive Powers of Labour” where he refers to industrial pin-making, that

The greatest improvement in the productive powers of labour, and the greater part of the skill, dexterity, and judgment with which it is any where directed or applied, seem to have been the effects of the division of labour. (*WN*, I.i.1)

He also argued that particular professional skills are not primarily a result of natural differences in individual human capacities, that is, of “innate abilities”, but rather emanate from learning-by-doing (or from learning-on-the-job):

The difference of natural talents in different men is, in reality, much less than we are aware of; and the very different genius which appears to distinguish men of different professions ... is not upon many occasions so much the cause, as the *effect* of the division of labour. The difference between the most dissimilar characters, between a philosopher and a common street porter, for example, seems to arise not so much from nature, as from habit, custom, and education. (*WN*, I.ii.4; emphasis added)

The increasing division of labour provides scope for gaining specialized experience, and thus for acquiring, developing, and enhancing particular skills. To the extent that it allows workers to gain such experience and to participate in the formation of such habits and customs, the increasing division of labour is skill-enhancing. However, Smith draws a most dismal picture of the impact of the division of labour on the “common labourer” when, in the context of a discussion of the need for public provision of education, he describes the consequences of industrial working conditions:

In the progress of the division of labour, the employment of the far greater part of those who live by labour, that is, of the great body of the people, comes to be confined to a few very simple operations; frequently to one or two. (*WN*, V.i.f.50)

The negative effects of the division of labour arise primarily from the fact that industrial production confines common workers to repetitive debilitating mechanical activity in the labour process—which, for Smith, is both *caused by* and *causing* the replacement of workers by machinery, as Tony Aspromourgos has pointed out:

The growth of labour productivity from division of labour is due to its making labourers like machines, with associated ill consequences for their intellectual and physical constitution, and their sensibilities It is this, really, which makes this specialization *partly* cause the invention of new machines: the resulting increase in the simplicity and repetitiveness—indeed, in the mechanical nature—of labour activity provides increasing scope for labour to be replaced with machines, including in this process the workers themselves perceiving potential innovations in machinery. (2009, p. 139)

The observation that progress (division of labour) exhibits a strongly deskilling bias prompted Smith to write one of his most-quoted paragraphs:

The man whose whole life is spent in performing a few simple operations, ... has no occasion to exert his understanding, or to exercise his invention in finding out expedients for removing difficulties which never occur. He naturally loses, therefore, the habit of such exertion, and generally becomes as stupid and ignorant as it is possible for a human creature to become. The torpor of his mind renders him, not only incapable of relishing or bearing a part in any rational conversation, but of conceiving any generous, noble, or tender sentiment His dexterity at his own particular trade seems, in this manner, to be acquired at the expence of his intellectual, social, and martial virtues. But in every improved and civilized society this is the state into which

the laboring poor, that is, the great body of the people, must necessarily fall, unless government takes some pains to prevent it. (*WN*, V.i.f.50)³

In Smith's view, technical change is not detrimental to labour as a whole—it increases overall employment—but this holds good only for a certain kind of labour, namely for unskilled labour. At the same time, however, the improvements and introduction of machinery that accompany the increasing division of labour are a substitute for skills. Thus, in Smith's view, technical change is predominantly unskilled-biased “in nature.”

In Smith's lifetime, as well as in his writings, machinery played not yet an important role, in contrast to the early- and mid-nineteenth century period in which Ricardo and Marx lived. Smith refers to the increased use of machinery as a particular kind of technical change that is likely to become more important in the future. In line with some of the later economic discussion on deskilling and skill-biased technological change and the sociological discussion on automatization (see Brugger 2013) Smith already anticipated the ambivalence of mechanisation for skilled workers. On the one hand, little imagination is needed to see that as a handicraft carpenter is replaced by a machine of which he remains, if at all, only a “functional part,” the skills demanded of him are radically reduced. On the other hand, for the development and maintenance of machinery a profound technical knowledge is needed like never before; hence, mechanisation is accompanied by a need for “machine-makers” and for “philosophers or men of speculation” (*WN*, I.i.9), as Smith pointed out. Thus in Smith's view technical change creates at the same time a well-educated “knowledge aristocracy,” whose only task is to invent new machinery (Rosenberg 1965, pp. 134–136), and an ignorant workforce of common labourers. Overall, it seems that Smith envisaged the deskilling tendency of technical change to be far stronger than the skill-enhancing one.

Like the progress optimist Smith the compensation optimists Say and McCulloch also discussed the deskilling or skill-displacing tendencies of innovations, at least in some short passages. McCulloch (1821, p. 115) contends that “no improvement of machinery can possibly diminish the demand for labour, or reduce the rate of wages.” However, like Smith, he saw in the possible deskilling or rather skill-displacing tendency of many innovations the only negative by-product that technical progress may have: “The only hardship which it [innovations] ever imposes on the labourer is, that in some cases it forces him to change his business” (McCulloch 1821, p. 115). Hence, for McCulloch it is possible that innovations make certain professions redundant. But he was very optimistic that displaced professionals will easily find new jobs in other industries where similar skills are needed. “The various subordinate branches of all the great departments of industry have so many things in common, that an individual who has attained to any considerable proficiency in one, has seldom much difficulty in attaining to a like proficiency in any other” (*ibid.*) Thus McCulloch, unlike Smith, does not believe that technical change as a whole has strong deskilling tendencies. Say illustrates with some examples the deskilling effects of machinery introduction (Say 1807, p. 40 f.), but we found no indication that he associates major social problems with deskilling technical progress.

³ As is well-known, according to Smith the negative consequences of the division of labour can be mitigated and partly offset by education (cf. *WN*, V.i.f.52–61).

Marx and Babbage

The most profound contributions on deskilling and skilling technical change were made by Karl Marx and Charles Babbage in the late nineteenth century, when classical economic theory was on its peak. In line with Smith, Marx argued that technological change was predominantly deskilling. Skilled professionals are replaced by unskilled women, children, or urban newcomers from rural areas. In sharp contrast to Smith, however, Marx also argued that technical change is not deskilling “by nature” or accidentally, but rather this is because capitalists deliberately search for deskilling innovations in order to break the bargaining power of skilled workers.

In his analysis of the development from medieval handicraft to the modern factory system Marx distinguished between the age of “manufactures” and “modern industry.” “Division of labour and manufactures” designates a phase of handicraft workshop industry in the seventeenth and eighteenth century, which preceded “modern industry,” associated by Marx with the early nineteenth century. What set off manufactures from earlier production of handicraft or industrial articles was a new organizational form: a workshop of handicraftsmen, each carrying out one or a few specific tasks, under capitalist control.⁴ In the workshop the labour process was divided into individual tasks, but the individual operations were still dependent on the skill of the workmen, and retained the character of a handicraft. Compared to “modern industry,” manufactures still lack a number of important characteristics. First, the existence of a hierarchical organizational structure prevented the full application of division of labour. Manufacturers still required skilled workers (“specialized detail labourers”), and the number of unskilled labourers could not be extended beyond certain limits.⁵ Secondly, the application of scientific principles in the rationalization of the labour process was hindered by the narrow technical basis of handicraft, since all steps in the production process had to be capable of being carried out by hand. Third, the greatest disadvantage of the manufacturing division of labour was the inability of capital to seize control of the whole labour time of manufacturing workers (Berg 1994, p. 63).

Although Marx stressed the deskilling bias of the manufacturing system,⁶ he noted that it also entailed skill-enhancing and/or skill-transforming elements: ‘Manufacture, in fact, produces the skill of the detail labourer, by reproducing and systematically driving to an extreme within the workshop, the naturally developed differentiation of trades’ (1954 [1867], p. 321). The detail labourer requires, and therefore acquires, very specific skills, compared to the artificer. However, according to Marx the overall skill content is nonetheless reduced:

⁴ ‘The principal basis of manufacture [is] the separation of the labourer from his means of production, and the conversion of these means into capital.... The rules of the guilds, ... by limiting most strictly the number of apprentices and journeymen that a single master could employ, prevented him from becoming a capitalist’ (1954 [1867], p. 339).

⁵ ‘Although manufacture creates ... a simple separation of the labourers into skilled and unskilled, simultaneously with their hierarchic arrangement in classes, yet the number of unskilled labourers, owing to the preponderating influence of the skilled, remains very limited.’ (1954 [1867], p. 346)

⁶ ‘The greater division of labour enables one worker to do the work of five, ten or twenty ... Labour is simplified. The special skill of the worker becomes worthless. Therefore, as labour becomes more unsatisfying, more repulsive, competition increases and wages decrease.’ (Marx 1977 [1849], pp. 225–6)

Manufacture begets, in every handicraft that it seizes upon, a class of so-called unskilled labourers, a class which handicraft strictly excluded. Alongside the hierarchic gradation there steps the simple separation of the labourers into skilled and unskilled. For the latter, the cost of apprenticeship vanishes; for the former, it diminishes, compared with that of artificers, in consequence of the functions being simplified. (1954 [1867], p. 331)

Yet handicraft skills, although simplified, are still of overwhelming importance in the “manufacturing division of labour”:

Since handicraft skill is the foundation of manufacture, and since the mechanization of manufacture as a whole possesses no objective framework which would be independent of the workers themselves, capital is constantly compelled to wrestle with the insubordination of the workers. (1954 [1867]: 346)

The novel element and characteristic feature of “modern industry,” as opposed to manufacturing, consists in the use of “machines” in the labour process, with far-reaching consequences:

Along with the tool, the skill of the workman in handling it passes over to the machine Thereby the technical foundation on which is based the division of labour in Manufacture, is swept away The organized group, peculiar to manufacture, is replaced by the connexion between the head workman and his few assistants. The essential division is, into workmen who are actually employed on the machines ... and into mere attendants (almost exclusively children) of these workmen. In addition ... there is a numerically unimportant class of persons, whose occupation it is to look after the whole of the machinery and repair it from time to time; such as engineers, mechanics, joiners, &c. This is a superior class of workmen, some of them scientifically educated, others brought up to a trade; it is distinct from the operating class. (1954 [1867], p. 396)

While the newly evolving, but “numerically unimportant” class of workers in modern industry consists of highly-skilled workmen, the main impact of the modern methods with regard to the former two classes is clearly associated by Marx with a deskilling bias of technical change:

Modern industry ... sweeps away by technical means the manufacturing division of labour, under which each man is bound hand and foot for life to a single detail-operation. At the same time, the capitalistic form of that industry reproduces this same division of labour in a still more monstrous shape; in the factory proper, by converting the workman into a living appendage of the machine; and everywhere outside the Factory, partly by the sporadic use of machinery and machine workers, partly by re-establishing the division of labour on a fresh basis by the general introduction of the labour of women and children, and of cheap and unskilled labour. (1954 [1867], pp. 454-455)

This *deskilling* bias is clearly considered by Marx as the major characteristic feature of modern industry in the early and mid-nineteenth century.⁷ But it is little noticed that Marx also suggested that this was already beginning to change, because the “technical basis” of modern industry is inherently “revolutionary” rather than conservative:

Modern industry ... is continually causing changes not only in the technical basis of production but also in the functions of the labourer ... Modern industry, by its very nature, ... necessitates variation of labour, fluency of function, universal mobility of the labourer Modern industry imposes the necessity of recognizing, as a fundamental law of production, variation of work, consequently fitness of the labourer for varied work, consequently the greatest possible development of his varied aptitudes. (1954 [1867], pp. 457–458)

For Marx, then, modern industry necessitated, and therefore would soon also enforce, the development of a better educated, less specialized, and more flexibly deployable workforce:

Modern industry, indeed, compels society, under penalty of death, to replace the detail-worker of to-day, crippled by life-long repetition of one and the same trivial operation, and thus reduced to the mere fragment of a man, by the fully developed individual, fit for a variety of labours, ready to face any change of production, and to whom the different social functions he performs, are but so many modes of giving free scope to his own natural and acquired powers. (1954 [1867], p. 45)

First signs of this change were already visible, Marx argued, in the early 1860s in terms of the establishment of technical and agricultural schools, which were introduced in order to prepare the workforce for more varied and more complicated tasks to be performed (*ibid.*).

A more optimistic view

Marx was very pessimistic about the deskilling bias of technical change, at least with regard to the phase of the manufacturing division of labour and the early phase of modern industry. Marx may be right that innovations induced by strikes and other class conflicts are predominantly deskilling, but this is not necessarily the case for the overall nineteenth-century technological change. The English polymath Charles Babbage was one of the economists who questioned the belief that technical change is predominantly deskilling. “*Frequently the new labour [demanded by new machines] requires [...] a higher degree of skill than the old [technique].*” (Babbage 1835, p. 335) His main argument is—following Smith—that just looking at the person running the machine is misleading, because this ignores “*the skill called into action in building the new factories, in constructing the new machinery*” (*ibid.*, p. 340). Hence, it may be true that the deskilling effect of introducing new machinery was for the production by itself

⁷ “The special skill of each individual insignificant factory operative vanishes as an infinitesimal quantity before the science, the gigantic physical forces, and the mass of labour that are embodied in the factory mechanism.” (1954 [1867], p. 399)

on average stronger than the skilling one (cf. O'Rourke et al. 2013, p. 1)—even that may be questioned: “*In the operation of the new machines too there were some which [...] required more rather than less skilled labour per unit of output*” (Habakkuk 1962, p. 154). But it should be clear that “*changes in the British economy went far deeper than just the transformation of industrial artisans into low-skill factory workers*” (Mokyr 2009, p. 348). The point is that machinery may have often downgraded handicraft workers to machinists repeating all day long a few manual tasks, but has at the same time created a demand for highly skilled engineers planning the production process, constructing new machinery, maintaining the machinery etc.; “*new factories needed managers, engineers, machinists, accountants, foremen, mechanics [...]*” (ibid.). Looking back on more than one-hundred years of mechanisation and automatization steadily more sectors became mechanized and therefore artisans are nowadays required more for cultural-artistic than for technical reasons. Concurrently the machinery became steadily more complex, resulting in more skill requirements: “*Improved machines, however, almost invariably required more skill to make them than did the simpler machines*” (Habakkuk 1962, p. 154). In addition, also the complexity of production organization, and controlling increased continuously. Whether on average the deskilling or the skilling effect of technical change in the nineteenth century was stronger is a very difficult empirical question, but one thing should be clear: The conclusion that technical change was entirely deskilling in the nineteenth century cannot be sustained: “*In many cases, the capital-intensive technique required, for its construction plus operation, more skilled labour per unit of output than the labour-intensive technique*” (ibid., p. 21).

Empirical evidence for skill-biased and deskilling technical change

In the last two decades there has been a growing empirical interest in the eighteenth- and nineteenth-century technical change bias. Among economic historians, it is common to speak of two industrialization phases between 1750 and 1900: the first occurred from ca. 1790 to 1830 and the second one from ca. 1850 to 1900 (Allen 2009). In the new growth theory literature there is a widespread presumption that the first industrialization was predominantly deskilling or skill-reducing, whereas the second one was skill-biased or skill-enhancing (for more details, see Brugger 2013).

Investigating empirically the eighteenth- and nineteenth-century bias of technological change comes with two main problems that are closely interrelated: 1) What are “skills”? 2) How should one measure “technical change bias”? Following Smith, in our understanding, professional skills are acquired from formal education like schooling, formal apprenticeships, or professional trainings *as well as* from learning-by-doing, work experience, and informal apprenticeships. Because skills and skill intensity can be measured only indirectly (Atack et al. 2004), empirical studies have to rely on *indirect indicators* or *approximations*, such as literacy rates, average years of schooling, numbers of patents, apprentices, or guild members, or the size of the female workforce and of child work, in order to obtain estimates of the technical change bias. Unfortunately, however, empirical results differ widely depending on which approximation or indirect indicator is used.

Accordingly, the question of how to measure the skill bias of technical change is a serious and still unresolved (and perhaps unresolvable) problem in empirical studies. What would constitute a good measure? Obviously, one would be looking for an “indicator” that is capable of registering changes in the demand for skills that emanate from the introduction of new technologies without being affected by other changes. However, no such measure seems to exist. Moreover, by posing the above question, one is lead immediately to ask various sub-questions: Should we be interested in the aggregate demand for skill (which is to some extent a result of compositional shifts in employment)? Or is it of more interest to follow only the transformation of skill requirements in particular industries as the technologies change (such as, for instance, the textile industry)? Or should we look at multiple levels of aggregation (in which case the further question emerges of how to combine findings from different levels of aggregation in a meaningful way)? We cannot pretend to have answers to these questions. However, in our view, it is clear that the introduction of a new technology in a particular industry must inevitably affect also the skill requirements of workers in some other industries, because the economic system consists of a set of interrelated industries mutually supplying each other with inputs. Measuring skill changes in aggregative terms therefore seems preferable and more informative than focusing on industry case studies alone. In the following, we report briefly on the results of various studies, organized along the “indicators” that have been used.

Literacy rates are very frequently employed as an approximation for the bias of technological change. Looking at literacy rates, industrialization as a whole appears to be a success story: In England, illiteracy rates decreased from over 90% in 1500 to less than 10% in 1900 (Cressy 1980, p. 177). At the beginning of the eighteenth century, industrial workers with a literacy rate of around 50–60% were amongst the best educated workforce compared with, for example, construction workers, butchers, or miners, whose literacy rates were much lower (ibid., p. 131–132). Country comparisons also show that more industrialized countries like England and the United States tended to have higher literacy rates in the mid-nineteenth century than less industrialized and more agrarian ones, like Austria or Spain (Vincent 2000). Adam Smith’s view that technical change was predominantly deskilling during his lifetime is contradicted by the empirical evidence: literacy rates increased strongly between 1710 and 1790 (Cressy 1980, p. 177). On the other hand, however, the data on literacy rates also support the hypothesis of a deskilling bias of the first industrialization phase because, in contrast to the strong increase in literacy rates in the long run, the overall rates show no clear trend for the period between 1790 and 1830, at least for English males. It must be noted, though, that literacy rates are a questionable indicator for the bias of technical change, because they undeniably depend on many social factors that are not directly related to the bias of technical change, such as political institutions, moral and cultural ideas, religion, or public funding for education. Furthermore, literacy increased in tandem for both skilled and unskilled workers (Nicholas and Nicholas 1992)—although the literacy rate of the former group has of course been consistently higher than that of the latter. Finally, literacy rates were on the rise long before the industrial revolution took off (Mokyr and Voth 2010, p. 30).

Export restrictions An unusual but interesting indicator of the skill-bias of technical change in the late eighteenth century can be seen in the establishment and subsequent repeal of the “Tudor laws”:

Throughout most of the mercantilist period, skills and technology were largely embodied in human beings, not in machines. Therefore, in 1718, 1750 and 1765 Parliament developed restrictive laws centered on skilled craftsmen [i.e., the Tudor laws]. Moving on in time to the period of early Classical economic thought and the beginning of the Industrial Revolution, machines began being produced as commodities and the technology embodied in them became an additional focus of legislation. As a result of this new focus, in 1774 and 1781 the Tudor laws were expanded to include severe restrictions on the export of machines. (Elmslie 1993, pp. 91-92)

Interestingly, in the first quarter of the nineteenth century, the restrictions on the emigration of skilled artisans were no longer considered necessary:

In 1825, the House of Commons appointed a Select Committee on Artisans and Machinery to look at the possibility of amending or repealing Britain’s laws restricting the exportation of certain types of machines as well as those prohibiting the emigration of skilled artisans. The Committee reported to the House that while the laws restricting “the combinations of workmen and the emigration of artisans” should be repealed, the effects of the laws on the exportation of machinery required “further inquiry.” (Ellis 1825, p. 386; quoted from Elmslie 1993, p. 92)

The development of the Tudor laws thus suggests that skilled artisans were still important for the English economy in the late eighteenth century, but their importance rapidly decreased in the 1820s. This would support the hypothesis that technical change was deskilling during the first industrialization. However, using changes in legislation as a skill-bias indicator is problematic, as the political process is often detached from economic realities and it is difficult to ascertain what were the “real” causes behind changes in legislation, and why they occurred at particular points in time.

Patents are another widely used indicator for ascertaining technical change biases. MacLeod (1988) investigated the English patent system and found, in support of Smith’s hypothesis, that in the late eighteenth century most inventions were labelled (by the inventors themselves) as “deskilling.” Patents of course have severe limitations as indicators for the bias of technical change. The propensity to patent an invention depends strongly on social, cultural, and economic circumstances, which greatly vary over time. Furthermore, the fact that a new technology has been patented tells us nothing about its adoption and diffusion, or its subsequent adaptation (cf. Bruland 2004, p. 123).

Recently, another very frequently used indicator for skill-biased technical change is the *wage premium*. The idea is that if wages for skilled workers are increasing faster than those for unskilled ones, this may be taken to indicate that because of skill-biased technological change demand for skilled workers is increasing faster than for unskilled

ones. Data on wage premiums were also used to estimate the technological bias of the eighteenth and nineteenth centuries. Studies on the historical development of the wage premium show some evidence for Smith's deskilling hypothesis: In accordance with Smith's theoretical suggestions the "skill premium" sharply dropped around 1730 in England (Rahman 2007). Results on the wage premium of the nineteenth century are more ambiguous: Supporting the hypothesis of predominately skill-biased technological change in the nineteenth century, Williamson and Lindert (1980) and Katz and Margo (2013) found that the wage premium for skilled workers increased during the nineteenth century in the United States. In contrast, Margo and Villafior (1987) found no evidence for a premium increase between 1820 and 1856. According to Feinstein (1988), the skill premium shows some marked up and down movements, but for the entire nineteenth century it shows no clear trend. For England, Williamson (1985) finds a sharp skill premium rise from the beginning of the nineteenth century to the mid-century, before it fell again in the late nineteenth century. Clark (2007, pp. 180–181) found that skill premiums for English workers were relatively stable between 1370 and 1800, before they fell sharply in the first half and again at the end of the nineteenth century.

Overall, what does the wage premium tell us? First, there is some evidence that Smith was right! During his lifetime, the wage premium sharply dropped in England. More contradictory is the empirical evidence for the nineteenth century: Katz and Margo (2013) found rising premiums in the United States, whereas Clark (2007) reported falling premiums in England. According to Williamson (1985) the "first" English industrial revolution was skill-biased and the "second" unskilled-biased. In contrast Mitch (1999, p. 269) found no clear upward trend for the wage premium. Hence, the evidence for skill- or unskilled-biased technological change based on wage premiums is mixed and contradictory: overall, the data show no clear trend for the wage premium in the frequently studied nineteenth century, neither for the United States nor for England. However, more generally skill premiums seem to be an insufficient approximation for the skill-bias of technical change, because they depend also on institutions, political ideas, the supply of skilled and unskilled labour, and the bargaining power of the two groups of workers. For example, nineteenth-century wage premiums depended strongly on the possibility of the trade unions to exclude unskilled workers from becoming members of the profession (Bruland 1982, p. 100).

Apprentice numbers are a further indicator frequently used for ascertaining biased technological change. Several studies indicate that formal and informal apprenticeships were of great importance for skill-acquisition in the eighteenth and nineteenth centuries (Feldman and Van der Beek 2016). "Apprenticeship was the main form of training" (Mokyr and Voth 2010, p. 31). Apprenticeships often, but not always, required previous formal schooling (Mitch 2004, p. 342), so that apprenticeships and schooling are complements and not substitutes, but informal apprentices more and more replaced guild members and artisanal professions (Mitch 2004, p. 348). Contrary to the Adam Smith hypothesis, the data on apprentice agreements also support the skill-bias hypothesis, because the number of apprentices rose sharply from 1710 to 1772 (Feldman and Van der Beek 2016). Wages for journeymen educated by apprentices also were significantly higher than those of unskilled labourers (Justman and Van der Beek 2015). On the other hand, Dunlop (1912) reports a strong erosion of the English formal apprenticeship system in the eighteenth century, thus seemingly supporting Smith's

view. However, with regard to skill acquisition those “new style apprenticeships,” which emerged in several industries (More 1980, p. 43), were not necessarily worse than the old ones. In the second half of the nineteenth century, apprenticeships have been very important education agreements for the English and German industry (Broadberry 2004). But while in England the importance of apprentices increased strongly, the apprenticeship rates in the United States declined markedly (Elbaum 1989). It seems that, at least for the later nineteenth century, apprentices became more important in particular for the English industry. Nevertheless, apprentice numbers are not a reliable approximation for skills, because apprenticeship durations differ widely and the shares of formal and informal apprenticeships are fluctuating considerably.

To summarize: literacy rates increased strongly between 1700 and 1900. Furthermore, apprentice numbers rose sharply in late nineteenth century, after having declined intermittently. Apart from “official” apprenticeships there are many indications that informal education (Mokyr and Voth 2010, p. 33) as well as learning-by-doing became much more important during the industrialization. For example, Bessen (2011) found a strong learning-by-doing effect for loom weavers, which also translated into large wage premiums for skilled weavers. There is an ongoing discussion on whether the wage premiums for skilled workers have increased during the industrial revolution or not. Even if there is no clear empirical evidence for the skilling or deskilling tendencies of industrialization, the hypothesis that technical change in the eighteenth and nineteenth centuries was deskilling in nature lacks empirical evidence. Hence, nobody found a clear evidence for the widely shared assumption that industrialization was predominantly deskilling. Overall, we find mixed empirical evidence for the bias of technical change but no clear trend that would suggest that technical change was predominantly deskilling in the eighteenth and nineteenth centuries. Also, it would be hard to explain why, after two-hundred years of deskilling technological change, the total number of skilled workers was still high at the end of the nineteenth century. According to Baxter (1868), there were 1.123.000 high-skilled workers, 3.819.000 low-skilled workers, and 2.830.000 unskilled labourers in England and Wales in 1867. Thus in 1867 more than 60% of the English and Welsh labour force was high-skilled or low-skilled, and only 40% unskilled.

The transformation of qualifications

Even if there was no clear deskilling bias of technological change, the required skills changed dramatically in the eighteenth and nineteenth centuries. As in all other phases of capitalism, skills became important that a generation ago did not even exist, while others have been completely superseded. According to Mokyr, “the need for different as opposed to fewer skills characterized the Industrial Revolution” (2009, p. 348). But with the perpetual emergence of new skill requirements and changing skill-contents, it must be recognized that “the distinction between skilled and unskilled labour is, of course, constantly shifting; technical progress creates new categories of employment and calls for continual redefinition of skill. Skilled labour at the beginning of the nineteenth century was very different from skilled labour at the end” (Habakkuk 1962, p. 22). While this makes intertemporal comparisons of overall skill levels rather difficult, some economic historians have argued that it is still possible to identify

marked changes in the *skill distribution* in the late nineteenth century. According to Mokyr, “the overall level of skills was not so much lower or higher, but their distribution was becoming more skewed” (2009, p. 348). By using the concept of a *skill distribution*, rather than a binary high/low skill distinction, it becomes possible to refer to changes in the skew of the skill distribution. So a more right skewed distribution, as described by Mokyr, signifies a growing concentration of people at the low skill level together with a smaller growing concentration at the high skill end. In the nineteenth century, this meant that “in addition to the deskilling of many of the old handicrafts there was also the rise of a new ‘labour aristocracy’ based on new production skills associated with the machinery” (von Tunzelmann 1995, p. 126). It could be argued, of course, that this is precisely what Smith had foreseen: In this reading, his prediction had been that industrialization will lead to *labour polarisation*. The industrialization generated a demand for well-educated and highly skilled (and handsomely paid) craftsmen, but also, at the same time, a much larger demand for unskilled labour (which often could, and was, performed by children and women): “The technological changes of the nineteenth century created a demand for highly skilled mechanics and engineers in the upper tail of the distribution, while possibly reducing the need for skills among manual labourers” (Mokyr and Voth 2010, p. 29). The evolution of a “labour aristocracy” in various British industries in the late nineteenth century has been vividly described by Gray (1981). In the United States in the second half of the nineteenth century, the manufacturing industry demanded increasingly high-skilled white-collar workers and low-skilled or unskilled manual workers, but middle-skilled artisans were hollowed out. However, this does not apply to the whole economy, where the share of high-skilled workers increased, that of the middle-skilled remained fairly stable, and that of low-skilled workers declined in the course of the nineteenth century (Katz and Margo 2013).

Qualification transformations are not similar to unskilled-biased technological change, but often generate grave social and economic disturbances as well. The perpetual shifting of required skills incessantly changes the social order and individuals’ places in society. This dynamic change of social order is always a very conflict-ridden and, for some members of society, quite painful process. The skills needed after the introduction of an innovation are typically not the same ones as those demanded before. Persons trained for professions that are made obsolete by technical change in general do not command the professional skills demanded afterwards, as Babbage succinctly observed: “Unfortunately, the class of persons driven out of the old employment are not always qualified for the new one” (1835, p. 335). The change in needed skills and the resulting change in people’s social position—“the two thousand persons thrown out of work are not exactly of the same class as those called into employment by the power-looms” (Babbage 1835, p. 339)—was the cause of many nineteenth-century conflicts. The transformation of qualifications in the eighteenth and nineteenth centuries often led to the paradoxical situation of unemployed or downgraded craftsmen, on the one hand, and a shortage of skilled labour, on the other hand. For example, the United States faced a strong shortage of high-skilled white-collar workers in the nineteenth century (Katz and Margo 2013, p. 7), and in Britain the industrialization of the late eighteenth and early nineteenth century led to a shortage of skilled workers (Pollard 1965, p. 160). The invention of cotton machines involved the establishment of two distinctive groups of workers: high-skilled and well-paid workers in the machine-

producing sector and unskilled low-wage workers in the cotton industry (Bruland 2004, p. 139). Scotland also faced the problem of skilled labour shortages in many industrial sectors such as mining, pottery and glass-making, bleaching, and nail-making (Devine 2004, p. 412). At the same time, industrialization caused incredibly bad working conditions for masses of unskilled men, women, and children. It was often the synchrony of the displacement of craftsmen by low-skilled industrial workers and the simultaneously rising demand for high-skilled workers, which made the industrialization process so ambivalent for skilled labourers. For example, Chin et al. (2006) show that the invention and adoption of the steam-engine in the nineteenth century has considerably increased the merchant marines' demand for high-skilled engineers, but simultaneously simplified the tasks to be performed by sailors and unskilled seamen. Similarly, the introduction of self-acting spinning mules on the one hand increased child-labour and the employment of unskilled women, but on the other hand it also led to a higher demand for skilled spinners (Lazonick 1979). This polarisation is found also in other industrial sectors, "occupations like papermaking in the early part of the century, and shoemaking in the later part, changed from hand to machine trades, and even if the skill involved was not less, it was certainly different and acquired in a different way" (More 1980, p. 47). Barnett (1925) also shows that many innovations in the late nineteenth century were skill-enhancing as well as skill-replacing. Thus, in the history of eighteenth- and nineteenth-century industrialization process, we find few innovations that have been unambiguously skill-reducing or skill-enhancing in nature. Most of them rather increased the demand for particular skills, which frequently had to be newly acquired, and at the same time made others redundant. Hence, industrialization led simultaneously to skilled labour shortages and a huge "Lumpenproletariat."

The induction of biased technological change

We found that many classical economists believed that technical change was predominantly deskilling during the eighteenth and nineteenth centuries. However, the authors under consideration put forward different views on what caused this bias. In accordance with recent discussions on technological change biases, the classical authors' views can be divided into two categories: those who argue that the bias is determined *exogenously* by technological trends and those who regard the bias as being *endogenously* determined by various socio-economic factors.

In the recent literature the increased demand for skilled labour in the twentieth century is seen by some authors as arising from a specific *General purpose technology*: new information and communication technologies that are skill-biased "by nature." Others hold that an increase in the relative supply of skilled labour has induced capital goods producers to direct their R&D activities towards developing new, more skilled-labour-complementary technologies. In a similar way, some classical authors also argued that the division of labour, mechanization, and industrialization simply happened to have a particular technological bias "by nature," while others suggested that social and economic factors, such as relative factor endowments, or strikes, bargaining power, etc., have at least co-determined the direction of technical change.

Biased technological change as an unintended by-product of progress

In Smith's view, the increasing division of labour was caused by enlarged markets that made it necessary to increase productivity in order to supply the rising demand. At the same time, increased division of labour and rising labour productivity also boosted demand because of falling commodity prices. Thus the increasing division of labour is both *induced by* enlarged markets and also *inducing* the enlargement of markets (see Brugger 2013, pp. 9–11). But for Smith, the deskilling bias of technical change was neither induced by an increasing endowment with unskilled labourers nor by attempts at breaking the wage bargaining power of skilled workers, but was rather an unintended by-product of the new production organization. Smith takes the deskilling nature of technical progress as *exogenously* given. This view was challenged by some studies that argue that relative factor endowments provided incentives for innovating in certain directions already in the late eighteenth and early nineteenth century.

Induced technical change and relative factor supplies

In much of the recent literature, relative factor endowments are considered to be the main driving force for the direction of technical change and it has been suggested that a comparison between England and the United States indicates that the technical change bias was strongly influenced by relative factor endowments already in the nineteenth century. Because in the United States the relative endowment with skilled labour was higher than in Britain, the wage differential between skilled and unskilled labour was much smaller in the United States than in England (Clark 1916, p. 392). Owing to skilled labour being relatively “cheaper” in the United States, more machinery that requires skilled labour for its operation was developed and used than in England (Brinley 1954, p. 165; Habakkuk 1962, pp. 151–152). This so-called “Habakkuk hypothesis,” according to which US factories used more skilled-labour complementary techniques because of the relative abundance of skilled labourers was supported by empirical evidence (see, for instance, Floud 1974). That relative factor endowments influenced the choice of techniques in the nineteenth century is supported also by comparative studies for specific industries, for instance by comparing the English and American cotton industry. Because of the relative abundance of skilled cotton-industry workers in Lancashire and their shortage in the United States the use of mule spinners was much more common in Lancashire (Sandberg 1969; Leunig 1996). More recently, Broadberry and Gupta (2009) showed that, due to high wages, English cotton manufacturing was unable to compete with Indian producers in the seventeenth and eighteenth centuries. The shortage of cheap labour in England, due to high productivity in other industries and higher living costs, was a serious disadvantage for the labour-intensive cotton sector. Lack of international competitiveness forced the English cotton industry to search for new techniques. This led to the development of “Spinning Mule” and “Spinning Jenny”—innovations that helped to restore the competitiveness of the English cotton industry. According to these studies, *differences* and *changes* in relative factor endowments strongly influenced the technical change bias in the eighteenth and nineteenth centuries.

Recently, the induced technical change argument was revived by Allen (2009), who claimed that England was characterized by a special price structure in the eighteenth

century: “Wages were high and energy was cheap. These prices led directly to the Industrial revolution by giving firms strong incentives to invent technologies that substituted capital and coal for labour” (2009, p. 22). Allen suggests that in the pre-industrialization phase, as well as in the early stages of the first industrialization, ‘high wages were a consequence of the vigorous economic growth of the period and led to further growth as new technologies were invented to economize on expensive English labour’ (2009, p. 55). According to Allen, the high wage economy was caused by the commercial expansion that preceded the early industrialization. It meant that many English could afford more education for their children, since in England “apprenticeship ... was the standard way of conveying craft skills. Typically, parents had to make a lump-sum payment to a master when their child was taken on, and the ability to save this sum was eased when incomes were high” (2009, p. 262). The prevalence of high wages “facilitated all sorts of skill acquisition. ... Widespread literacy, numeracy and craft competence reflected the demand for skills in the advanced economies, and the high wages those economies generated gave workers the money to pay for schooling and apprenticeships” (2009, pp. 55–56). Consequently, “eighteenth-century Britain was much more abundantly endowed with human capital, and that is an important reason for the technological breakthroughs of the period. ... Britain had more inventors because the population became more literate, numerate and skilled” (2009, pp. 238–239). Allen agrees with Mokyr (2002), that “the Industrial Revolution would have come to naught if the vital few had not been supported by second- and third-tier inventors, who made the micro-inventions that improved the efficiency and extended the scope of the macro-inventions” (2009, p. 240). The key to British technological success was that its rich endowment of competent skilled artisans gave it a comparative advantage in micro-inventions (2009, p. 258 see also Meisenzahl and Mokyr 2012).

The eighteenth-century high wages not only provided the means for more skill acquisition, but also strong incentives for introducing labour-saving technologies. In the period from 1760 to 1830, Allen argues, “innovation in the British cotton industry relentlessly saved labour, the scarce and expensive factor of production” (2009, p. 184). Allen further suggests dividing the innumerable inventions of the British industrial revolution into “macro-inventions,” which are associated with technological breakthroughs due to new scientific or technical knowledge, and “micro-inventions,” which consist of adaptations and minor improvements due to “local learning.” The former, he argues, exhibited a particular bias, which made them suitable only for Britain, not for Continental Europe: High wages and cheap energy led to the invention of labour-saving and energy-intensive (i.e., coal-intensive) technologies. The subsequent “micro-inventions,” however, then exhibited no particular bias anymore:

In their youth, they [the inventions] were decidedly British in their biases. As they matured, these biases wore away, and the inventions were adapted to any circumstances. At that point, the Industrial Revolution diffused to the continent [and] to North America. ... This life span took a century and a half. (2009, p. 136)

Allen seeks to support his thesis by focusing on selected examples of British micro-inventions. One such example is the self-acting mule, which was invented in the late 1820s by Richard Roberts: “His aim was to eliminate the jobs of the high wage

spinners who had operated the mules, and in that he succeeded—thus providing a neat example of factor prices directing invention” (2009, p. 208) However, Allen is well aware of the standard objection to factor-price induced technical change: Profit-maximizing firms are interested in reducing unit production costs in general and therefore are indifferent between saving capital or labour.⁸ He seeks to address this objection—rather insufficiently—by emphasizing “the cost of R&D and the expectations about the bias of the resulting technology” (2009, p. 137). He is clear about the fact that

implicit in this analysis is the idea that firms undertaking R&D knew what they were aiming at, at least in economic terms. It would be hard to argue with this assumption in the case of the inventions that increased the use of coal, for they were clearly aimed at changing factor proportions in the direction of a cheaper input. The assumption is not as immediately obvious in the case of machines. Was Hargreaves aiming at saving labour with the spinning jenny and Arkwright with the water frame? (Allen 2009, p. 142)

Deskilling innovations as a weapon in the class struggle

Unlike the recent contributions to biased technological change, some classical economists have argued that the *endogenous* bias of technological change is not due to relative factor endowments and relative factor prices, but is also, and perhaps mainly, an instrument for raising the capitalists’ bargaining power in the class struggle. As outlined above, one-hundred years after Smith, Marx also diagnosed predominantly deskilling tendencies of technical change. But unlike Smith, for whom the deskilling bias is an unintended by-product of the increasing division of labour, Marx sees technical deskilling as a bourgeois weapon in the class struggle: By substituting machines for workers, capitalists deliberately seek to reduce skilled workers’ bargaining power. Machinists are easy to replace by unskilled workers, including women and children, and therefore have a much weaker bargaining position than highly specialised and well-trained workers. In times of high strike frequency, capitalists got shown quite plainly that specialised skilled workers are pivotal for production and difficult to replace. Therefore, strikes provided incentives for capitalists to search for deskilling innovations: “In England, strikes have regularly given rise to the invention and application of new machines. Machines were, it may be said, the weapon employed by the capitalists to quell the revolt of specialist labour” (Marx 1963, pp. 167–168) Marx asserted that “from 1825 onwards, almost all the new inventions were the result of collisions between the worker and the employer who sought at all costs to depreciate the workers’ specialized ability” (1963, p. 140).

⁸ Allen rightly notes that “a high wage might not imply high labour costs if the high wage workers were more productive than the low wage workers” (2009, p. 143). He fails to note, however, that because in standard neoclassical theory in equilibrium each factor must be remunerated according to its marginal productivity, there is no incentive to direct the R&D activity towards the saving of any particular factor (Salter 1960). For a critical discussion of the neoclassical approach to induced technical change, see Brugger and Gehrke (2017).

Well, the nineteenth century was a time of strong skilled-craftsmen unions, at least in some sectors (see Foster 1974), deep mistrust between management and labour (Magee 2004, pp. 93–94), high labour turnover, and on-going resistance of skilled workers (Bruland 2004, p. 139). There is a relatively comprehensive empirical literature on whether Marx's hypothesis was correct that major strikes have induced capitalists to search for skilled-labour-saving innovations. Most notable is Nathan Rosenberg's article from 1969, entitled "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices," which emphasized the bargaining-power-reducing component of nineteenth-century innovations:

The apparent recalcitrance of nineteenth-century English labor, especially skilled labor, in accepting the discipline and the terms of factory employment provided an inducement to technical change. ... The view was widely expressed in nineteenth-century England ... that strikes were a major reason for innovations We have, moreover, the evidence of numerous inventors themselves, who testified that they undertook the search process, which led to a particular invention, as the result of a strike or the threat of a strike. (Rosenberg 1969, p. 12)

According to Rosenberg, many skilled-labour-saving innovations appear irrational, because they did not reduce unit costs, at least from a short-run perspective. Or, as Bruland put it, entrepreneurs apparently based their choice of production methods not only on the production costs that are associated with a certain technique, but also took into account which kind of labour was needed to run a certain machinery, whether the needed workers are organized in unions or not, and whether they are easy to replace in a strike, etc. (1982, p. 95). Hence, the strong anti-skilled labour bias of many innovations is not fully explained by short-run profit maximization: "*It may well even be that the apparently irrational determination of so many nineteenth-century firms to introduce labour-saving innovations (irrational from the point of view of modern theory) really arose from their determination to engage in rational long-term planning—a procedure which was impossible as long as strikes possibilities by indispensable skilled personnel hung like a sword of Damocles over their heads.*" (Rosenberg 1969, p. 22) Apart from Rosenberg, authors such as Habakkuk (1962), Floud (1974, p. 105), Lazonick (1979, pp. 233 ff.), Bruland (1982), MacLeod (1988, p. 170), and Mokyr (1990) have also recognized incentives for entrepreneurs to direct the search for inventions towards methods that reduce the bargaining position of workers: "There are several instances where the desire to diminish the bargaining power of skilled craft labour provided a strong incentive to install machines which replaced it by unskilled labour" (Habakkuk 1962, p. 153), and "inventors wished to substitute away from labor to reduce the bargaining power of unions or because they believed their workers to be untrustworthy" (Mokyr 1990, p. 165). Hence "The result [of on-going struggles between skilled workers and entrepreneurs] can be seen in the changing structure of the labour force. Between 1841 and 1861 the proportion of skilled workers in the Oldham industry declined from about 70 to 40 per cent (with equivalent increases in the number of labouring and semi-skilled jobs)" (Foster 1974, p. 227) Even if the deskilling pressure of nineteenth-century technical change is often overestimated (von Tunzelmann 1995, p. 111), there is sufficient evidence to conclude that strikes have been a major factor in inducing entrepreneurs to search for and implement bargaining-power-reducing

innovations, as stated by Marx. Besides introducing deskilling innovations employers also followed a second tactic in order to impair the workers' bargaining position by installing "a new pacemaker grade inside the labor force" (Foster 1974, p. 231). By paying skilled senior workers for the whole work process and inviting them to hire unskilled workers on their own account, skilled workers became a kind of "semi-capitalists."

As Marx noted, other nineteenth-century political economists shared his view that breaking the workers' bargaining power was a strong incentive to innovate in a certain direction. Charles Babbage, in particular, also pointed out that strikes may have induced innovations that are to the detriment of workers: "The improvements which are often made in machinery in consequence of "a strike" amongst the workmen, most frequently do injury, of greater or less duration, to that particular class which gave rise to them" (Babbage 1835, p. 297) And Andrew Ure (1969 [1861], pp. 364–71), in his typical anti-union manner, even made strikes responsible for the workers' distress, arguing that the latter had forced cotton producers to "request" the invention of less skill-intensive techniques. He contended that strikes have been "injuries inflicted on their own body by the unions" (*ibid.*, p. 364), in the sense that "during a disastrous turmoil of this kind, in Hyde, Stayley-bridge, and the adjoining factory townships, several of the capitalists, [...] had recourse to the celebrated machinists Messrs. Sharp and Co., of Manchester, requesting them to direct the inventive talents of their partner, Mr. Roberts, to the construction of a self-acting mule, in order to emancipate the trade from galling slavery and impeding ruin" (*ibid.*, pp. 366–367). In this way, increased mechanization enabled the capitalist to get rid of "restive spinners, and to become once more master of his mill, which is no small advantage" (*ibid.*, p. 365). According to Ure, without those class struggles and the high costs they inflicted on the owners of the cotton mills, further mechanization and displacement of skilled workers would not have taken place at this time. This is confirmed also by Bruland, who noted that "within the British textile industry in the early nineteenth century, a direct causal relationship can be identified between particular arenas of industrial conflict and particular kinds of technical innovations" (1982, p. 94). According to Bruland, also in the case of spinners, wool-combers, and calico printers, strikes have led to further mechanization and replacement of skilled workers:

We can thus understand certain specific avenues of technical change, and hence certain aspects of the technical structure of production, in terms of the struggles over power, control and distribution, which are endemic within production systems in capitalist economies. (Bruland 1982, p. 94)

Marx identified the manufacturing division of labour as an instrument of capitalists to gain power over the workers and control over the labour process. Numerous contributions to the "labour process" literature have pursued and confirmed Marx's perspective, for both the nineteenth and twentieth centuries. Harry Braverman (1974), who started this stream of literature, applied it to explain the rise of a white-collar working class through the mechanization of office work, which led to the deskilling and displacing of clerical workers. In his

classic study, he also noted the importance of what has since been called the “Babbage Principle.”⁹ It states that:

the master manufacturer, by dividing the work to be executed into different processes, each requiring different degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult, and sufficient strength to execute the most laborious, of those operations into which the art is divided. (Babbage 1835, pp. 175-176)

The underlying rationale of Babbage’s principle is that a worker who performs high-skill tasks must receive a wage commensurate to his skill level, even though he regularly has to perform work of lower skill levels as well. If instead the labour process is divided among several workers, however, overall labour costs can be considerably reduced by assigning only high-skill tasks to high-cost workers, and by limiting low-skill tasks to low-paid workers. According to Braverman, “the most common mode of lowering the cost of labor is exemplified by the Babbage principle: break it up into its simplest elements. ... The labor power capable of performing the process may be purchased more cheaply as dissociated elements than as a capacity integrated in a single worker. ... Every step in the labor process is divorced, so far as possible, from special knowledge and training and reduced to simple labor” (1974, pp. 79–83). Along partly similar lines, Marglin (1974) has attempted to explain the direction of technological and organizational change associated with the industrial revolution by “the resort of economically and politically powerful classes to innovation in order to change the distribution of income in their favor (rather than to increase its size)” (1974, p. 104). More specifically, he claimed that neither “the minute division of labor that characterized the putting-out system” nor “the development of the centralized organization that characterizes the factory system ... took place primarily for reasons of technical superiority. Rather than providing more output for the same inputs, these innovations in work organization were introduced so that the capitalist got himself a larger share of the pie at the expense of the worker, and it is only the *subsequent* growth in the size of the pie that has obscured the class interest that was at the root of these innovations” (1974, p. 62).

Conclusion

The main aim of this article is to compare the views of the classical political economists on the effects of technical change on labour markets, in particular on the demand for skilled and unskilled labor, with the empirical evidence that emerges from studies of economic historians. In Smith’s view, technical change is predominantly deskilling.

⁹ Although Braverman is frequently credited with having coined this term, it had in fact already been used by Alfred Marshall, who referred to it as “Babbage’s great principle of economical production, according to which every worker is set to the most difficult and important tasks of which he is capable, and only to those” (1919, p. 149).

The lean empirical evidence we could find for the period of Smith's lifetime confirms that many innovations have been deskilling in nature, but there are also indications for skill-biased change. One-hundred years later, Marx stated that entrepreneurs deliberately search for innovations with a deskilling bias, in order to break skilled workers' bargaining power. The evidence assembled by economic historians for the late nineteenth century shows that strikes and other situations where entrepreneurs got shown the bargaining power of skilled workers quite plainly gave them a strong incentive to search for bargaining power reducing—and thus deskilling—new technologies. While Smith regarded the deskilling bias as an unintended by-product of technological change, Marx argued that under certain circumstances deskilling is the goal of innovations. Some classical authors—most notably Charles Babbage—argued that labelling nineteenth-century technological change a just “deskilling” is an untenable simplification. Artisans were not only replaced by unskilled machinists, but also a variety of newly needed skills arose. Empirical evidence indicates that nineteenth-century technical change was accompanied by marked *skill transformations*—various skills became redundant while new ones arose—but we found no evidence that technical change was on average predominantly deskilling in this period. Hence, the often-viewed opinion that nineteenth-century technical change had a strong overall bias against skilled labour may be due to a generalisation of catchy stories, but lacks empirical support. In fact, nineteenth-century technical change came with an extensive transformation of demanded skills and a change in the skew of the skill distribution, rather than with a deskilling bias alone.

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