*The "Machine Breakers" and the Industrial Revolution**

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1. Introduction

The early phase of the industrialization process in Britain was characterized by a considerable number of machine-breaking riots. All the great innovations in textile technology were, at some point of time, smashed. John Kay's flying shuttle met strong resistance and workers rioted against its introduction in 1758,1785-7,1810-13 and 1822. Hargreaves' spinning jenny was attacked by several mobs (1767, 1769 and 1779). In 1779 there were also assaults against Arkwright-type factories. The power loom was the target of the Lancashire Luddites in 1812.[1] Although these labour disturbances have been the subject of extensive historical investigations, there is still little consensus among historians about the exact nature and significance of this form of resistance to innovation

Recently Joel Mokyr has put forward a new interpretation of the machine-breaking riots, in particular of the Luddite outbreaks of 1811-12.[2] According

* I am indebted to Nick Von Tunzelmann for discussions and valuable suggestions. An earlier version of this paper was presented at the Eighth J.A. Schumpeter Society Conference, in Manchester, June 2000. I thank Joel Mokyr and the other participants for helpful comments. Confusions and remaining errors are entirely my own.

[1] P.Mantoux, *The Industrial Revolution in the Eighteenth Century* (London, 1928;2nd rev. edn., Chicago,1983), p. 208;M.Berg, *The Age of Manufactures. Industry, Innovation and Work in Britain 1700-1820* , (Oxford 1985), pp. 260-263.

[2] J. Mokyr, *The Lever of Riches*, (Oxford 1990); J.Mokyr , "Progress and inertia in technological change" in J. James and M. Thomas (eds.), *Capitalism in Context*, (Chicago 1994); J.Mokyr, "Technological change,1700-1830" in R.Floud and D. McCloskey (eds.), *The Economic History of Britain since 1700*.Vol I, (2nd edn., Cambridge 1994) and J. Mokyr, "Cardwell's law and the political economy of technological progress" *Research Policy*, 23 (1994), pp. 561-574.

to Mokyr, the introduction of a new technology is generally resisted by those social groups endowed with assets (in terms of capital equipment or labour skills) specific to the old technology and that cannot be easily shifted to different forms of investment. Assuming the superiority of the new technology in the market place, Mokyr suggests that resistance to innovation may take place in two different forms. The first one is the attempt to influence the political power by means of lobbying activities in order to achieve the introduction of regulations obstructing the diffusion of new technologies. The second one is the use of illegal actions (sabotage and violence) aimed at intimidating the would-be adopters of the new technologies.

Mokyr's contention is that the machine-breaking riots of the British Industrial Revolution can be interpreted using this theoretical framework. He outlines a typical pattern of evolution in the resistance to innovation exerted by workers whose skills were superseded by the new technologies. Initially they tried, through a prolonged campaign of petitions to Parliament, to obtain the enforcement of old regulations or the adoption of new legislation that would have hampered the adoption of new technologies. Parliament did not support their claims. Thus, in a second attempt, workers resorted to machine-breaking activities. But also these attempts were unsuccessful, because of the strong repression by the government. The British Parliament and the British government resolutely took the side of the innovators, not allowing the "vested interests" of the workers specialized in the old technologies to block the course of technological progress. The fact that political power in Britain was so much favourable to the innovators was a further advantage for Britain compared to the other European countries in the early stages of industrialization, which might help to explain the classical question "why Britain was first".

The aim of this paper is to scrutinize the explanation of the machine-breaking riots proposed by Mokyr. I will focus mainly on the historical record of the machine-breaking riots characterizing the development of the English textile industry in the period 1750-1850. My main contention is that Mokyr's overall thesis is untenable. Although he is correct in pointing to social conflicts about technological choices, his explanation is too simplified and relies on a reductionist (because essentially one-dimensional) representation of the dynamics of technical change.

Historians of technology have shown that, in the early phase of industrialization, *several technological options were open* and the problem was to select out of a set of different technological paths. Therefore, I argue that it is more appropriate to conceive the machine-breaking riots in terms of a struggle over what Sabel and Zeitlin have referred to as "historical alternatives to industrialization",[3] rather than, as Mokyr does, a conflict between the supporters of a progressive technological path and the vested interests favouring a stagnating status-quo. Furthermore, I argue that the resistance of the working class to the introduction of new techniques was rooted in a quite sophisticated and articulated conceptualization of the dynamics of technical change and that in this conceptualization a notion very similar to the concept of "appropriate technology" of modern studies in development has a central role.

The paper is organized as follows. Section 2 briefly sketches the historical debate on machine-breaking riots during the British Industrial Revolution. In section 3 Mokyr's interpretation is summarized. Then, drawing both on historical accounts of the riots and on studies of technological change during the Industrial Revolution, I will point out the limitations of Mokyr's study. In section 4 I propose a different interpretation, which is based on previous works by Maxine Berg and Nick Von Tunzelmann.

2. The historical analysis of "machine-breaking": a short overview of the debate

The machine-breaking riots, according to what might be called the "traditional" interpretation,[4] were essentially a technophobic attempt to halt the industrialization process. The disturbances were the spasmodic

[3] Sabel C. and J. Zeitlin, "Historical alternatives to mass production: politics, markets and technologies in nineteenth century industrialization", *Past and Present* 108 (1985), pp. 134-176 and C. Sabel and J. Zeitlin, "Stories, strategies, structures: rethinking historical alternatives to mass production" in C.Sabel and J. Zeitlin (eds.), *World of Possibilities*, (Cambridge,1997), pp.1-33.

[4] T.S. Ashton, *The Industrial Revolution 1760-1830*, (Oxford 1957), D. Bythell, *The Handloom Weavers*, (Cambridge 1969) and P. Mantoux, *Industrial Revolution* can be considered as representative examples of what I have termed here the "traditional" historical interpretation of the machine-breaking riots.

reaction of workers to economic hardship. Furthermore, according to the traditional view, "the resistance which the workers sought to offer to the progress of machinery could not supply a remedy to their troubles.... it obviously had no chance of success, as the whole trend of events was against it".[5]

For example, Bythell has seen the destruction of the power looms in the cotton factories as an expression of "pointless physical violence" and "blind vandalism".[6] According to Bythell, the main determinant of these outbreaks was the desperate economic condition of the handloom weavers. The handloom weavers were the victims of the process of industrialization of the British economy, nevertheless their unhappy situation is not *directly* imputable to technical changes:

> More than any other group, the cotton handloom weavers demonstrate that the real "black spots" of Britain's classic industrial revolution are to be found, not in the early textile factories or even in the mines (bad as both they were) but in the swollen armies of unskilled domestic outworkers in those trades unaffected by new machines and new methods.[7]

Bythell goes further, arguing that the prolonged period of economic agony of the handloom weavers can be entirely accounted for by the slow diffusion process of the power loom (due to the difficulties encountered in solving its initial technical drawbacks). Had the solution to the technical limitations of the power loom been found before, we would have seen a more rapid diffusion process and the fortune of the handloom weavers would have resembled the happier one of the cotton spinners.[8]

[5] P. Mantoux, *Industrial Revolution*, p. 408.
[6] Bythell, *Handloom Weavers*, p.180 and p.199. The power-looms were the targets of the Luddite riots in Lancashire in 1812. In 1826 there was another outbreak in the same region during which several power-looms were destroyed.
[7] Bythell, *Handloom Weavers*, p.271.
[8] "[I]t is possible to...argue that in reality the powerloom was a blessing and not a curse to the handloom weavers, and that their problems were greatest in the earlier period, not because "the machine" was displacing them, but because it was *not* displacing them" (Bythell, *Handloom Weavers*, p.271).

Bythell also argues that the machine-breaking riots did not have long-term consequences. In particular, he rejects the view of both contemporaries and historians who have suggested that the slow diffusion of some technical innovations (like the power loom) during the Industrial Revolution was due to fear of working class hostility to them.[9] As we have seen, his explanation relies entirely on the technical limitations of the early versions of these innovations.

The account of the Hammonds is perhaps one of the first not in line with the "traditional" interpretation. In their judgment the workers' reaction should not be regarded as irrational. Given the deterioration of their living standards brought about by the industrialization process, the workers looked for protection in the maintenance and revival of the old customary rights. Not finding their claims supported by Parliament, they tried to enforce their prerogatives through direct action.[10]

Thus, perhaps not surprisingly, the historical debate on the machine-breaking riots runs parallel to the debate on the standard of living. The so called "optimists", those who argue that the Industrial Revolution determined an improvement in the living standards of the working classes, tend to see machine breaking as an irrational reaction to an unfortunate, but transitory, economic condition. On the other hand, the "pessimists", those who claim that industrialization was accompanied by deteriorating living standards, consider the motives of this form of protest in a different way.

In his famous paper "The Machine Breakers",[11] Hobsbawm, one of the leading "pessimists", openly questioned the traditional interpretation and warned against accounts which assume that the behaviour of the early labour movement was simply a blind and irrational reaction to the pressure of a highly unfavourable economic condition. In most cases

[9] According to William Radcliffe - an entrepreneur with "a very shrewd appraisal of the problems facing the weaving industry at the beginning of the [nineteenth] century" (Bythell, *Handloom Weavers*,p.71) - the destruction in 1792 of one of the first factories using the powerloom (the Grimshaw factory in Manchester) was the main determinant of the delayed adoption of this technique in the weaving industry.

[10] J.L. Hammond and B. Hammond, *The Rise of Modern Industry*, (London 1957).

[11] E.J. Hobsbawm, "The machine breakers" in E.J. Hobsbawm, *Labouring Men. Studies in the History of Labour*, (London 1964).

workers' actions were rather the result of sophisticated strategies aimed at achieving specific and clearly identified goals. Those, like Bythell, who have considered the machine-breaking riots as a "throwback to the disorganized activities of a pre-industrial age",[12] have had a hard time in explaining their persistence, their duration, the difficulties of the authorities in repressing them, not to speak of the degree of organization and self restraint shown by the "machine breakers".[13]

Hence, in order to avoid misjudgments, according to Hobsbawm, one has to take into account that the actions against machinery were not a compulsive response to economic distress, but popular manifestations characterized by a multifarious and complex array of motivations. The first important distinction to be drawn is the one between the machine-wrecking activities related to a genuine working class hostility to the introduction of a new technology, and those activities which were simply a means to put pressure on the employers and force them to accommodate other industrial grievances. Hobsbawm has called this latter form "collective bargaining by riots". In the early phase of industrialization, when there were limited possibilities for the organizing of effective strikes, this pressure tactic was capable of achieving remarkable results.

Many authors have welcomed Hobsbawm's distinctions and tried to find out whether waves of workers' resistance to the introduction of machinery can be seen as ways for expressing other demands. For example, in his book on the Luddite riots, Thomis has described the destruction of machinery as a way of securing wage increases during a phase of prolonged economic distress.[14] More generally, according to Thomis, in the early development of the British labour movement it is possible to recognize two parallel approaches for the expression of specific industrial grievances. The first one was characterized by the use of constitutional forms (such as Parliamentary petitions) and by attempts at organizing effective "combinations" among workers. The second one

[12] Bythell, *Handloom Weavers*, p.180.

[13] Bythell, for example, admits that the 1826 riots during which power looms were wrecked "were not wholly disorganized, for the ability which the rioters showed in evading the military on three successive days [24-25-26 April 1826] demonstrates a considerable tactical skill on the part of the leaders" (Bythell, *Handloom Weavers*, p.200).

[14] M.I. Thomis, *The Luddites. Machine Breaking in Regency England*, (London 1970).

adopted the methods of direct action and industrial sabotage. Although Thomis acknowledges that in specific cases the boundaries between these two approaches are quite blurred, he maintains that the distinction has an important interpretative power. According to him, it can be shown that, where it was possible for workers to organize themselves and to set up legal and semi-legal practices for expressing their demands, they did not resort to use violence and direct action.[15]

Thomis's account has been criticized by Rule and Randall.[16] In their view his attempt at clearly discriminating the different forms of workers' struggle is more dictated by the desire of downplaying the role of direct action and of unconstitutional forms of protest in the early development of the British labour movement, than by the genuine need of elaborating a comprehensive appraisal of the actual historical profile of workers' activity. On this point, Randall has noticed that in many cases machine-breaking was mainly used by well-organized and strongly unionized groups of skilled workers and it was mixed in a very sophisticated way with other more orthodox forms of trade union activity (petitioning, strikes, etc.).

Hobsbawm also pointed to the complex and interwoven mixture of peaceful negotiation and semi-legal and illegal practices characterizing the manifestation of workers' discontent. Thus, the concept of "collective bargaining by riots" has been used by Thomis and other scholars well beyond Hobsbawm's original intention. Destruction of machinery as a means of expressing other grievances is frequently assumed to be a valid general explanation for *all* the machine-breaking activities of the Industrial Revolution, instead of a useful notion in the interpretation of a limited number of specific cases. It is also worth noting that the improper and extensive use of this notion has the effect of minimizing the hostility of the workers to the adoption of new machinery.

The destruction of machinery had a highly symbolic power that should not be underestimated. The choice of such a target was not a simple tactical device, but it was an expression of a genuine aversion of the

[15] Thomis, *Luddites*, p.133.
[16] J. Rule, *The Labouring Classes in Early Industrial England 1750-1850*, (London 1986) and A.Randall, *Before the Luddites*, (Cambridge 1991).

workers to the introduction of new technologies.[17] In the rest of the paper, I focus particularly on these specific cases, however it must be taken into account that there were other episodes in which machine breaking was used in a tactical way to put pressure on employers and to enforce solidarity among workers.

E. P. Thompson in his book *The Making of the English Working Class* moved further in the direction indicated by Hobsbawm and has considered the machine-breaking riots (in particular the Luddite outbreaks) as "a manifestation of working-class culture of greater independence and complexity", expressing "an alternative political economy to the one of laissez faire".[18] According to Thompson, the behaviour of the working class rested on an "industrial moral economy", which did not accept the rise of an unregulated industrial capitalism. The "industrial moral economy" of the machine breakers appealed to old customary regulations, but it should not be understood in "reactionary" terms:

> ....we may see Luddism as a moment of transitional conflict. On the one hand, it looked backward to old customs and paternalist legislation...on the other hand, it tried to revive ancient rights in order to establish new precedents.....All these demands looked forwards, as much as backwards, and they contained within them the shadowy image, not so much of a paternalist, but of a democratic community, in which industrial growth should be regulated according to ethical priorities and the pursuit of profits subordinated to human needs.[19]

The "industrial moral economy" did not have any special anti-capitalist character. It was the ideology of small communities of skilled and specialized workers. Since the beginning of the eighteenth century, unions ("combinations" in the parlance of the time) of skilled workers were able both to protect and in some cases even to improve their living

[17] "There can, of course, be no doubt of the great feeling of opposition to new machines" (Hobsbawm, "Machine breakers", p.10). See also D. Noble, "Present tense technology", in *Democracy. A Journal of Political Renewal and Radical Change*, 3 (1983), pp. 8-24,70-82, 71-93 and. A. Randall, *Before the Luddites*, (Cambridge 1991).
[18] E. P. Thompson, *The Making of the English Working Class*, (London 1963),p.603.
[19] E.P. Thompson, *The Making of the English Working Class*, p.603.

standards.[20] They were accustomed to capitalist labour relations and they did not oppose the market as a system for organizing production. They affirmed that markets should operate within the stable set of limits established by custom. Hence, the continuous reference to "fair" or "unfair" prices.[21] A typical example of these regulations is the Spitalfields Acts of 1773 regulating the piece rates of London silk weavers.

Another still-open issue of debate is the degree of effectiveness of machine-breaking activities. Bythell, who views machine breaking mainly as an irrational and desperate reaction to the introduction of the new technologies, maintains that the impact of these actions was very limited.[22] Thomis in his analysis of the Luddite riots claims that the outbreaks did not delay the diffusion process of the new technologies (gig mill and shearing frames in Yorkshire, power loom in Lancashire). Moreover, he points out that in those areas where the employers, following the riots, agreed to accept wage increases (Nottinghamshire), these wage-concessions lasted for a very short time span.[23]

In their more recent contributions, Rule and Randall have sharply criticized this view and they have found evidence vindicating the previous claim of Hobsbawm that "[machine-breaking] was by no means the hopelessly ineffective weapon that it has been made out to be".[24] In several cases the process of diffusion of a new technology was actually halted or delayed because of the machine-breaking riots. The most striking case is that of the threshing machine, whose rapid diffusion process was stopped by the Captain Swing riots of 1830-31. The threshing machine did not reappear on large scale in the English countryside until the 1850s.[25] Randall shows that in the wool-textile industry the workers' resistance to innovation was highly successful in postponing the adoption of different types of machines for a remarkable period of time.[26]

[20] J.Rule, *Labouring Classes in Early Industrial England*, p. 255.
[21] On the notion of "industrial moral economy" see especially A. Randall, *Before the Luddites*.
[22] Bythell, *Handloom Weavers*, p.233.
[23] Thomis, *Luddites*, p.161.
[24] Hobsbawm, "Machine breakers", p.17.
[25] E. J. Hobsbawm and G. Rude', *Captain Swing*, (London 1969).
[26] Randall, *Before the Luddites*, pp. 82-83.

3. Joel Mokyr and the political economy of technical change

Mokyr has recently noticed that in most cases technological progress has a double-edged character.[27] In other words, technological changes are seldom conceivable as Pareto-improvement shifts; instead they should be viewed as transformations involving winners and losers. The losers are those groups of society endowed with specific assets[28] dedicated to the old technology. If these assets cannot be mobilized, the introduction of the new technology in the economic system will procure a substantial loss to them. Hence, it is rational for those groups to resist the introduction of the innovation. Mokyr assumes that, if market mechanisms alone would be responsible for the selection process of technologies, the new (better performing) technology would inevitably supersede the old one. Given this assumption, resistance to the innovation is eminently based on non-market forces and can assume two different forms. The first one is the attempt to influence the political process in order to achieve the introduction or the enforcement of regulation that will prevent the diffusion of the new technology. The second one is the use of violence, boycotts and machine-breaking to intimidate the would-be adopters of the new technology.[29]

Krusell and Rios-Rull have built a formal model aimed at capturing the main insights of Mokyr' s argumentation.[30] In their model, the final good is produced by a Cobb-Douglas technology in skilled and unskilled

[27] J. Mokyr, *Lever of Riches*, pp. 178-179.

[28] "These assets could be formal skills, tacit knowledge, reputation, specialized equipment, ownership of certain natural resources, barriers to entry that secured monopoly positions and community-based non-pecuniary assets"(J. Mokyr, "Cardwell's law", p.564)

[29] One might note that a similar thesis was originally formulated by Habakkuk: "[E]ach fresh technical development created vested interests, among capitalists as well as labourers, in particular forms of industrial organization and production which acted as an impediment to the adoption of succeeding technological developments." (H.J. Habakkuk, *American and British Technology in the Nineteenth Century*, (Cambridge 1962),p.125).

[30] P. Krusell and J.V. Rios-Rull "Vested interests in a positive theory of stagnation and growth", *Review of Economic Studies* 63 (1996), pp. 301-329. It is important to note that Mokyr explicitly considers the model of Krusell and Rios-Rull as a good representation of his views. See Mokyr, "Cardwell's law", p.564.

labour. Technical change is depicted as a Hicks-neutral shift of the Cobb-Douglas production function. Being the skills specific to a particular technological vintage, workers endowed with skills in technology t (where t is the index of the technological vintage) will naturally oppose the introduction of the more productive technology t+1, because its adoption would completely depreciate the value of their skills.

The two building blocks of the model are the skill-accumulation process and the politico-equilibrium process. In the political process, it is decided through a majority rule whether or not the development of new technology is allowed. This interplay between skill-accumulation and politico-equilibrium may generate very different outcomes: alternating cycles of growth and stagnation, continuous growth, and uninterrupted stagnation.

The analytical framework elaborated by Mokyr and formalized by Krusell and Rios-Rull (which Mokyr has labelled "the political economy of technological change") is a quite general one. Mokyr's emphasis on the latent conflicts underlying the process of technological change is surely appropriate. Mokyr also stresses that the outcomes of these struggles are highly uncertain. As we have seen, the conflicts take the form of non-market processes, and the struggle is fought on a multiple level and a wide variety of resources can be mobilized into it. Thus, it is very difficult to make *a-priori* assessments of the relative strength of the various social groups involved. However, if we take into account that the benefits of innovation (through a reduction of prices) usually accrue to a more widespread and heterogeneous set of agents than the losses, it is likely that, because of the free-rider problem, the groups against the new technology will find it easier to organize and resist. For this reason, one might expect that the most common case will be the one in which the adoption of new technologies is prevented. According to Mokyr, this is the main determinant of the so-called "Cardwell Law", which states that technologically progressive societies have been such only for relatively short periods of time. The "political economy of technological change" explains why social attitudes favourable to continuous technological development are unlikely to be conserved for a long time. Thus, when looking at the historical record we can see the technological leadership moving from one country to another.

In his contributions, Mokyr applies this conceptualization to the case of the British Industrial Revolution. According to Mokyr, many technical advances in this period displaced labour skills. These labour skills were an important asset of small and strongly unionized groups of workers (like the Yorkshire woollen workers), who were able to restrict access to their trade and enjoy a consistent employment rent. Thus, when they became aware of the menace that the new technologies exerted on their rent position, they tried to resist their introduction. In the period in question, the British Parliament had to examine a lot of petitions asking for the enforcement of old quality regulations[31] and/or the introduction of new restrictions, which would have hindered the introduction of new machinery. Parliament refused to meet these requests, resolutely taking the side of the innovators. The "vested interests", as Mokyr calls them, then resorted to direct action, employing industrial sabotage and violence. However, the British government stood firm and suppressed the riots with determination. According to Mokyr, the different attitudes of the ruling establishment towards the resistance against innovation in England and on the Continent is a major factor explaining "why Britain was first".[32]

From a cursory look at the recent literature on the machine-breaking riots, it would seem that Mokyr has been able to elaborate an analytical framework capable of providing a new and fairly persuasive account of the workers' resistance to machinery during the Industrial Revolution. Moreover, his analysis has the merit of fitting a more general interpretation of the industrialization process in Britain.

However, on closer scrutiny, his explanation neglects some important aspects emerging from recent historical accounts and for these reason it appears to be flawed at least in three respects.

Firstly, it is true that the resistance was often exerted by workers, who saw the value of their labour skills being eroded by the introduction of new technologies, but it must be borne in mind that the machine breakers enjoyed fairly widespread popular support, undoubtedly well beyond

[31] The enforcement of quality regulations strictly prescribing the production procedures (i.e. materials and tools to be used) would have made *de facto* illegal the use of the new technologies.

[32] Mokyr, "Technological change 1700-1830", pp. 34-35.

the social groups directly affected by the introduction of the innovations. Hence, the difficulties of the authorities in repressing the riots. This does not fit very well with Mokyr's representation of the machine breakers as an "Olsonian" lobby. The historical analysis of Randall shows clearly that other motivations, besides the rational preservation of self-interest were of key importance.[33]

In their Parliamentary campaign, the woollen workers did not show hostility towards innovation in itself, but towards the disruptive impact that one specific path of technological advance had on an, until then, well-functioning system of production. Their model of political economy "placed a premium on stability, regulation and custom"[34], therefore they made a case for the accommodation of technological change within the existing forms of industrial organization.

Secondly, as it is apparent from the model of Krusell and Rios Rull, what Mokyr has in mind is a contrast between those who support the introduction of a better performing (more productive) technology, and those who favour the status quo. On the contrary, the evidence from the history of technology suggests instead that the most common case in the period of the Industrial Revolution was the one of "competing technologies": several technological options were available and many of them were capable of generating productivity increases. Thus, it is not appropriate to focus exclusively on the developments in mechanized and capital-intensive techniques, for also the performance of hand tools and small-scale machinery was constantly improved.[35] Furthermore, recent

[33] "[I]nnovation was frequently met with resistance not merely from those in immediate danger of losing work nor even from those under longer term threat but also from other trades and groups not threatened in any way by the machine...[Among the machine breakers we find] a cross section of the workforce as a whole" (Randall, *Before the Luddites*, p. 44).

[34] Randall, *Before the Luddites*, p.227. For an appraisal of the key role played by customary practices in small craft economies see Sabel and Zeitlin, "Historical alternatives", pp. 152-154.

[35] M.Berg, *The Machinery Question and the Making of Political Economy 1815-1848*, (Cambridge 1980), p.177. In the textile industry power driven technologies were generally more productive than hand technologies only for low quality yarns and cloths. See N. Von Tunzelmann, *Steam Power and British Industrialization to 1860*, (Oxford 1978), chap 7.

work in the economics of technological change has pointed out that usually the performance of techniques is improved over time along not only one but several dimensions. Comparisons between two technological paths will generally yield no clear-cut results (one technique can be better along some of the relevant dimensions and worse along the others). For these reasons, a one-dimensional representation of technical change does not generally seem appropriate. Contemporary studies have also emphasized the irreversibility features of technological advances. In particular, it has been shown that it can be misleading to assume that technologies achieving market domination are in some sense "superior" to alternative options. Increasing returns, due to network or learning effects, may well determine the possibility of "lock-ins" into, in some definite sense, inferior technologies.[36] These considerations indicate that, when appraising historical episodes of resistance to new technologies, due attention should be paid to *all* the lines of technological advance that were *potentially* available in that specific historical instance.[37]

Thirdly, when considering the choice of technique, we should take into account the influence exerted by the need of eliciting workers' effort. Bowles has formally analyzed choice-of- technique issues when factor productivities are not given but when they are affected by factor prices, as in the efficiency wages hypothesis. In this case we have to take into account that choice of techniques can have an impact on the position of the worker's reaction curve in the effort/wage space.[38] It can be shown that, under these hypotheses, the cost-minimizing choice of technique will not generally be socially optimal. Entrepreneurs will place a high premium on the capacity of techniques of eliciting workers' effort (by "homogenizing" labour, by "intensifying" work or by facilitating the monitoring of the labour process). Von Tunzelmann has outlined the central role played by the necessity of extracting workers'

[36] See, among others, R. Cowan "Technological variety and competition. Issues of diffusion and intervention" in OECD, *Technology and Productivity*, (Paris 1991).
[37] Here it is important to remark the pre-emptive character of many machine-breaking disturbances. See Randall, *Before the Luddites*, p.150.
[38] S. Bowles, "The production process in a competitive economy: Walrasian, Neo-Hobbesian and Marxian models." *American Economic Review* 75 (1985), pp. 16-36.

effort in the diffusion of machine-paced production in the textile industry during the 1830s and 1840s.[39] In his view, the speed of machinery was the crucial variable determining the choice of technique. Power costs dictated the optimal speed of machinery and thereby the amount of worker's effort per unit of labour time. The decline of power costs, which followed the technical improvements of the steam engine in the 1830s and in 1840s, was translated into higher speed of machinery and, as a consequence, in intensified labour for the workers. This excursus into "radical" contributions illustrates the theoretical (and historical) relevance of a conflict on the choice of techniques of a different type to the one stressed by Mokyr. For our purposes, it is important to bear in mind that cost-minimizing decisions in capitalist economies will not generally lead to choice of techniques that are in any sense socially optimal (and this is true especially for the historical period we are considering here). In the context of the machine breaking riots, Hobsbawm has noticed that: "In some cases, indeed, the resistance to the machine was quite consciously resistance to the machine *in the hands of the capitalist*".[40]

4. The machine-breaking riots: an alternative interpretation

An alternative interpretation of the machine-breaking riots would better square with the historical accounts. In my view, these disturbances were an expression of a more general conflict over the pattern of industrialization that divided British society at large. Moreover, workers' resistance was pointing to the necessity of undertaking a different development path characterized *by different technologies and different forms of industrial organization.*

My argument will be developed in three steps. In the first step I link the machine-breaking riots with the counterfactual dimension of the standard of living debate. In the second step I discuss the pattern of technical change in the British Industrial Revolution. In the third step I

[39] Von Tunzelmann, *Steam Power,* pp. 202-225.
[40] Hobsbawm,"Machine breakers", p. 15 italics added.

take up the issue of the interaction between technological and organizational changes.

4.1 The standard of living debate. As we have previously noticed, the debate on the "machine breakers" seems to parallel the standard of living debate. The "optimists" consider machine-breaking as an ill-conceived response to a transitory situation of economic distress, whereas for the "pessimists" the resistance to technology was aimed at minimizing some of the economic and social costs of the industrialization process.

As Hartwell and Engerman firstly noticed, the standard of living debate has both a factual dimension (how did the standard of living of the British working class change during the process of industrialisation?) and a counterfactual dimension.[41] The counterfactual dimension can be set out by means of two different interrogatives: 1) how would the living standards have changed without the Industrial Revolution ? 2) would it have been in some way possible to guarantee better living standards for the working classes during the industrialization process ? Von Tunzelmann has maintained that the second counterfactual is the really relevant one, because it the one that many authors in the pessimists' field more or less explicitly endorse. The optimists mistakenly have tried to rebut pessimists' arguments by dealing mainly with the first counterfactual.[42]

In the early 1980s, Lindert and Williamson claimed to have definitely solved the factual dimension of the standard of living debate in favour of the optimists.[43] According to them, real wages were stationary until the 1820s and from the 1820s to the 1850s they increased about 80 per cent. These results have been recently criticized by Feinstein. In his view, Lindert and Williamson' s index of real wages contains serious flaws.

[41] R.M. Hartwell and S. Engerman, "Models of immiserisation: the theoretical basis of pessimism" in A.J. Taylor (ed.), *The Standard of Living in Britain in the Industrial Revolution,* (London 1975).

[42] N.Von Tunzelmann "The standard of living debate and optimal economic growth" in J. Mokyr (ed.), *The Economics of the Industrial Revolution,* (New York 1985).

[43] P.H. Lindert and J. Williamson "English workers' living standards during the Industrial Revolution: a new look", *Economic History Review* 36 (1983), pp. 1-25.

Feinstein, in his turn, has produced an alternative index of real wages. His index shows between the 1780s and the 1850s an increase of less than 30 per cent. Taking into account a proper discount for the so-called "disamenities" of industrialization, it is the pessimists' case to be vindicated.[44] For our purposes, it is important to note that Feinstein considers England as an economy with an abundant supply of labour, which exerted a constant downward pressure on real wages. Furthermore, Feinstein does not disdain to note the adverse impact of technological and organizational innovations on real wages:

> The... pressure on industrial wages was exacerbated in many sectors as skilled male craftsmen were displaced or challenged by the introduction of machinery, by changes in the organization which undermined their traditional position, and by employment of female workers in traditional male occupations such as weaving of woollen cloth.[45]

Von Tunzelmann's dismissal of the first counterfactual interrogative formulated by Hartwell and Engerman is surely appropriate. Industrialization *per se* has never been an issue of debate for the pessimists. The evidence suggests that industrial change *per se* was not an issue also for the working classes.[46] When technical innovations facilitated work without reducing employment, they were never resisted. Berg has argued that the bulk of the "machinery debate" was on the economic and social implications of a specific *direction* of technical advances.[47] It was a particular industrialization pattern to be contested, not industrialization *per se*.

For these reasons it is the second counterfactual interrogative that appears to be the crucial issue both for the standard of living debate and for our discussion. Von Tunzelmann has shown the historical

[44] C. Feinstein "Pessimism perpetuated: real wages and the standard of living in Britain during and after the Industrial Revolution", *Journal of Economic History* 58 (1998), pp. 625-658.

[45] Feinstein, "Pessimism perpetuated", p. 651.

[46] See for example the writings collected in M. Berg (ed.), *Technology and Toil in Nineteenth Century Britain*, (London 1979).

[47] Berg, *Machinery Question* especially pp. 16-17 and p.76

viability of alternative (and more favourable to the working classes) growth paths during the period in question.[48] Notably, these alternative growth paths would have been less capital intensive than the actual one.

At this juncture, I suggest taking a further step and assume that capital accumulation takes place around specific techniques, as it was suggested by P. David.[49] For David the choice of a specific point in the "spectrum of techniques" in a specific historical instance (due to the localized nature of technological change) will exert a powerful influence on the future course of technical advances and, more generally, on the pattern of economic growth. Thus, in David's approach, the achievement of an alternative growth path would have required, at the very beginning of the process, the adoption of a different technique. These considerations provide an interesting link between the standard of living debate and choice-of-technique issues in the course of the industrialization.

Further, Broadberry has expanded the model proposed by David. He considers that in the period in question there was a relationship of complementarity between capital and unskilled labour, whereas capital and skilled labour were essentially substitutes. From this, it follows the use and refinement of specific techniques involve the complementary adoption of specific forms of work organisation geared to the more or less intensive use of skilled or unskilled labour. However, this statement should not be understood in strictly deterministic terms. Rather, what is meant here is that capital accumulation takes place on localized trajectories along which technological and management practices co-evolve.[50]

All these considerations lead us to re-examine the pattern of technical change during the British Industrial Revolution.

[48] Von Tunzelmann ("Standard of living and optimal economic growth") uses a standard neoclassical growth model to identify the optimal growth path. Then he contrasts the optimal path with the actual path.
[49] P.A. David, *Technical Choice, Innovation and Economic Growth*, (Cambridge 1975).
[50] S.Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850-1990*, (Cambridge 1997).

4.2 Technical change in the British Industrial Revolution. Landes has appraised the character of technological advances during the Industrial Revolution in terms of three interrelated innovational trends:

> ....the substitution of machines – rapid, regular, precise, tireless – for human skill and effort; the substitution of inanimate for animate sources of power, in particular, the introduction of engines for converting heat into work, thereby opening to man a new and almost unlimited supply of energy; the use of new and more abundant raw materials, in particular, the substitution of mineral for vegetable or animal substances.[51]

Further, for Landes, "the logic" of this complex of technical advances compelled the adoption of a new system of production, the factory system.[52]

Historical research has questioned the concomitance of these innovational trends. Although over time the three trends identified by Landes gained progressively momentum and began to mutually reinforce each other, in what is usually considered the classical period of the British Industrial Revolution (1760-1830), it was undoubtedly the first innovational trend to predominate.[53]

In his more recent works Von Tunzelmann has attempted to give a new account of the pattern of technical change in the British Industrial Revolution, using Dosi's paradigm/trajectory approach.[54-55] One of the main merits of this approach is to deal explicitly with the crucial issue of the direction of technical advance; a theme that was

[51] D. S. Landes, *The Unbound Prometheus*, (Cambridge 1969) p. 41.
[52] D. Landes, "What do bosses really do?", *Journal of Economic History* 46 (1986),pp. 585-624.
[53] T. Bruland and K. Smith "Industrialization, steam power and economic historiography", *Economy and Society* 10(1981), pp. 88-101.
[54] N. Von Tunzelmann "Technology in the early nineteenth century" in R. Floud and D. McCloskey (eds.), *The Economic History of Britain since 1700*, (2nd edn., Cambridge 1994);N. Von Tunzelmann "Time-saving technical change: the cotton industry in the English Industrial Revolution", *Explorations in Economic History*, 32 (1995), pp.1-27 and N. Von Tunzelmann, *Technology and Industrial Progress*, (Cheltenham 1995)
[55] G. Dosi "Technological paradigms and technological trajectories", *Research Policy*, 11 (1982), pp. 147-162. and G.Dosi "Sources, procedures and microeconomic effects of innovation", *Journal of Economic Literature*, 26 (1988), pp. 1120-1171.

not appropriately tackled by Landes.[56] For Von Tunzelmann, the prevailing technological paradigm in manufacturing can be summarized under the broad heading of "mechanization". This means that the creation or refinement of mechanical contrivances was considered the privileged solution for "technical" problem-solving arising in the course of the production process. In most cases, this amounted to substituting machines for human skills, and converting the to-and-fro motions of human arms and feet into rotary motion.[57] In Dosi's approach, technological trajectories are generated by the interplay between the "autonomous" drift of technology within the boundaries of the technological paradigm with a particular set of inducement factors of an economic type (relative prices and income distribution). Economic inducement factors are likely to play a role in determining the specific direction of the technological trajectory when the paradigm is in its emerging stage. Over time the heuristics get progressively established and technical advances become increasingly localized and irreversible.[58]

In the early phase of the Industrial Revolution, the amalgamation of inducement factors with the internal logic of the technological paradigm generated a stable set of *time-saving* heuristics.[59] Time-saving is to be intended in the sense of reducing the time needed for producing a given amount of output. This was usually achieved (i) by reducing 'downtime' (the period in which the machine is not in operation), (ii) by increasing throughput, (iii) by increasing machine co-ordination, (iv) by increasing system co-ordination. It is important to note that these features are an indication of a productive system already geared to mass production.

[56] On the shortcomings of Landes's analysis of technical change see Bruland and Smith "Industrialization" and T. Bruland "Industrial conflict as a source of technical innovation: three cases", *Economy and Society*,11 (1982), pp. 88-101.

[57] Von Tunzelmann *Technology and Industrial Progress*, p. 105.

[58] See Dosi "Sources",pp 1142-1145. This is fully consistent with the analysis presented in David (*Technical Choice)* to which I have previously referred. Dosi' s heuristics are in some sense analogous to the "elastic barriers" that in David's approach constrain the accumulation of capital around a specific technique.

[59] Time-saving heuristics appeared to accommodate fairly well both the factor scarcities prevailing at that time and the technical imbalances arising from the successive mechanization of distinct stages of the production process. See Von Tunzelmann, "Time-saving technical change".

Concomitant with the formation of the time-saving technological heuristics outlined by Von Tunzelmann, powerful "deskilling" inducement factors were also at work and, over time, they also became crystallized in the set of heuristics guiding the search for innovations (note that technological trajectories are multidimensional, so there is no contradiction here).[60] Historical studies of innovation in this period provide ample indication of the existence of this deskilling trajectory. According to Nicholas and Nicholas:

> Britain's industrialization process was set in the mold of unskilled-labour intensive production at an early stage. The factory deskilled and proletarianized the work force by destroying old skills, substituting female and child laborers for skilled male workers, and relying on power-driven machinery which created jobs that required no formal skills or even rudimentary levels of literacy.[61]

Using data from Manufacturing Censuses, Goldin and Sokoloff have produced strong empirical evidence supporting the existence of what they call "a stream of technological change" aimed at substituting women and children for adult skilled males in the United States during the first phase of the industrialization process. As they appropriately suggest it is correct to assume that a similar technological trajectory was unfolding in Britain.[62] This is also confirmed by accounts of single technological innovations. Bruland analyzes the cases of three important textile innovations and shows that bypassing the bargaining power of highly skilled groups of workers was the main target of innovative efforts.[63] In chapter 15 of Volume I of *Capital*, Marx noticed three effects on labour

[60] This is also acknowledged by Von Tunzelmann (see Von Tunzelmann "Time-saving technical change", p.3), although he assigns the predominant role to time-saving. Perhaps it is more correct to say that the two assumed the same importance.
[61] S. J. Nicholas and J. Nicholas "Male literacy, deskilling and the Industrial Revolution", *Journal of Interdisciplinary History*, 23 (1992), pp 17-18.
[62] See C. Goldin and K. Sokoloff "Women, children and industrialization in the early republic: evidence from manufacturing censuses", *Journal of Economic History* 42 (1982), pp 741-774.
[63] Bruland, "Industrial conflict".

determined by the introduction of new machines: 1) "labour dilution", that is substitution of skilled (mainly adult male) with unskilled labour (women and children), 2) prolonging the working day (because new machinery was mainly used in the factories), 3) intensification of work (speeding up of machinery made labourers work harder). Furthermore, "deskilling" technical advances quite often determined an intensification of labour (mainly achieved by means of speeding up the production process).

In many cases machine-breaking riots were an expression of workers' opposition to the consolidation of this "unskilled labour intensive" trajectory of technical advances. As a consequence, machine-breaking was never indiscriminate, but highly selective, being based on an accurate evaluation of the labour requirements of new machinery. Von Tunzelmann has stressed that opposition to labour "dilution" was the main determinant of the Luddite revolt.

> Highly skilled labour could always prove something of a bottleneck for expansion , and it was here that some explicit attempts were made to replace such skilled labour with unskilled labour or machinery ("deskilling"), particularly during the Napoleonic Wars. The most famous episode was the outbreak of "Luddism" – attacks on machinery – which is often equated with a general opposition to machinery, though in practice was mostly opposition to the replacement of skilled with unskilled labour.[64]

Many historical accounts have shown that the main impact of innovations was to reduce the bargaining power of particular groups of skilled workers. In resisting the introduction of new technologies, these, groups of workers tried to preserve a customary system of recruitment, which allowed them to exert some control on the supply of labour. This aspect is aptly emphasized by Rule:

> Manufacturing artisans....largely accepted the idea that bargaining was

[64] Von Tunzelmann, *Technology and Industrial Progress*,p. 111

> one of the processes which determined the price they got for selling their skilled labour power, but they...thought in terms of a "fair" labour market, not an "open" self-regulating one in which employers could employ whom they chose at the lowest price. A fair labour market was one in which the respective powers of capital and labour were not hugely unequal. In such a system of exchange, the exclusive rights to a trade were recognized and machines did not displace [skilled] labour simply to enhance the profits of capital. Machinery in itself was not necessarily an issue. The Nottinghamshire Luddites did not oppose knitting frames, *they opposed [technical] adaptations which enable some hosiers to employ cheap labour in the production of inferior stockings.*[65]

Two of the targets of the Luddite riots (the wide frames in Nottinghamshire, the shearing frames in Yorkshire) were machines with a clear deskilling impact. The attacks of the Lancashire Luddites on the power loom, instead, should be seen as a form of opposition to factory work.

Randall has provided a careful analysis of the arguments used by the woollen workers in their petitions against the gig mill and the shearing frame. His analysis is very important because it sheds light on the workers' attitude towards technical change In many cases the workers asked for the enforcement of old legislation, which would have prevented the adoption of the new machinery. However, in his study, Randall emphasizes that the woollen workers' parliamentary campaign was based not only on an appeal to the old legislation. The woollen workers (but this holds true also for the political proposals of other textile workers) formulated a complex set of arguments with which they repudiated the unrestrained introduction of new machines on economic grounds. The woollen workers also formulated a wide variety of proposals, more or less explicitly asking for the introduction of a policy towards technology. Overall, one cannot avoid the impression that the different forms of opposition of the English working class seemed to be more aimed at re-directing the development of technical advances in a particular directions rather than at stopping it.

[65] Rule, "Against innovation ?", p.186 [italics mine]

In the woollen workers' case, a number of proposals suggested a "negotiated introduction" of machinery. They proposed a period of trial of the new technologies during which the social benefits and social costs were to be accurately assessed. In other cases the textile workers required the introduction of technical modifications to the innovation so that it could be smoothly integrated into the traditional organization of production.[66]

Another quite common policy proposal was the introduction of a tax on new machinery. For example, the handloom weavers in their Parliamentary campaign asked for a tax on the use of the power loom. The main rationale behind this proposal was to balance the "unfair" advantage of the power loom, which had been designed to be used by cheap segments of the workforce.[67] The revenue from the tax would have been used to constitute a relief fund for the displaced workers.

Given these considerations, I would suggest that machine-breaking disturbances and other less visible forms of resistance to innovation should be considered as the expression of working class hostility to the specific direction taken by technical change during the Industrial Revolution. In terms of the paradigm/trajectory approach, the actual issue at stake was the exploration of the space of technological opportunities and the choice of a specific direction within this space. The machine-breaking riots and other expressions of opposition to innovations can be better understood as attempts of the working class to explicitly question the technological path that was undertaken. It is also worth recalling the pre-emptive character of the attacks on machinery. This seems to reflect workers' awareness of that technological change is an inherently cumulative and irreversible process. Thus, to retain some chances of success, the opposition had to be exerted in the early phases of the development of a new technology.[68] Finally, the highly symbolic power of machine

[66] Randall, *Before the Luddites,* p. 73-74.

[67] Berg,*Machinery Question,* p. 242.

[68] "The cloth dressers' actions, like those of scribblers and spinners, were essentially pre-emptive, recognizing that once machinery was allowed to secure a significant part of the trade, all employers would be forced to introduce them in order to compete and the dressers' trade would be irretrievably undermined" (Randall, *Before the Luddites,* p.150)

destruction, the use of threatening letters (together with the creation of "mythological" characters like General Ludd and Captain Swing) can be seen as revealing the intention of exerting a fundamental shock to the "visionary ideas" governing the design of machinery and, in this way, conditioning the prevailing technological heuristics.

The availability of a relatively wide "spectrum of techniques" in the textile industry has been acknowledged, among others, by Habakkuk:

> On balance, it seems reasonable to suppose that in the textile industry in the first half of the nineteenth century, the range of possible methods of production was sufficiently wide and continuous in respect to the proportions in which they used capital and labour...[69]

In the textile industry a number of intermediate technologies (e.g. the Jacquard loom, or the dandy loom) were also available. These technologies were adopted mainly in domestic manufacture and used in the production of high-quality goods. Although their diffusion was limited to small sections of the cotton-weaving industry, in these sections they were able to sustain successfully the technological competition with the power loom.[70] Another important innovation was the "pendulum loom" invented by John Sadler which was capable of raising substantially the productivity of hand weaving.[71]

It is worth noting that in some cases workers' resistance was highly effective and it did succeed in shaping the direction of technical advances in a favourable way. The most striking example for the textile industry is the case of the spinning mule The original mule was invented by

[69] Habakkuk, *American and British Technology*, p.29 See also Berg, *Age of Manufactures*, p. 220.

[70] Von Tunzelmann, *Steam Power*, pp.201-202.

[71] Berg,*Age of Manufactures* p. 267. R. Samuel, cites several examples in which it was possible to achieve high increases of productivity with a limited mechanization of the production processes. Moreover the productivity gains deriving from the improvement of hand tools and small-scale machinery are in his view unduly underestimated. Therefore "[it is not] possible to equate the new mode of production with the factory system....[in several cases] rising demand was met by a proliferation of small producers" (R. Samuel, "The Workshop of the world: steam power and hand technology in Mid-Victorian Britain", *History Workshop*, 3 (1977), p.28)

Crompton in 1779. It was not power-driven and it was explicitly designed for being employed in cottage production.[72] Whereas Arkwright's water frame displaced completely the skill of the operator, Crompton's mule required a considerable degree of dexterity and skill. Notwithstanding its use of qualified labour, the mule quite soon succeeded in winning the competition with the water frame because Arkwright's machine could produce only coarse yarns. Crompton's mule, instead, was more versatile and could produce a wide range of yarns, including the finest counts.

Successive technical developments allowed the use of the spinning mule in factories. However mule spinners were able to maintain a high degree of control of the labour process and of the development of technology. This achievement was partly the result of the fact that the spinners were able to keep their role in the maintenance and improvement of the machines. Although the ability of mule spinners in securing wage increases and acceptable working conditions is often seen as the result of the application of "modern" unionism practices, more accurate investigations have shown that this is not the case. As Rule puts it: "their unionism was much in the traditional style of skilled workers".[73] Catling has described their efforts for maintaining an influential position on the course of technical advances. This passage is particularly illuminating:

> ... [every mule spinner] proceeded to tune and adjust each of his own particular pair of mules with little respect for the intention of the maker and the principles of engineering. Before very long, no two mules were alike... Much could have been done to standardize maintenance and setting procedures of the mule. In the end little was done. It continued to be necessary to have one fully qualified spinner to look after each pair of mules; because of the many peculiarities which the individual tuning engendered, it was usually unwise to move a spinner about other than in exceptional circumstances.[74]

[72] See R. Hills "Hargreaves, Arkwright and Crompton: why three inventors?", *Textile History*, 10 (1979), pp. 114-126.
[73] See Rule, *Labouring Classes* p.270.
[74] H. Catling, *The Spinning Mule*, (Newton Abbot 1970), p. 149.

As a consequence, in the initial phase, the trajectory of incremental technical change of the common mule, at least initially, did not substitute mule spinners with other forms of cheap labour.[75] Robert's self-actor (patented in 1825 and 1830), which was explicitly designed to circumvent the position of the mule spinners, marked a watershed in this line of development.

4.3 Organizational change in the British Industrial Revolution. Alongside the formation of a stable set of technological heuristics, a process of consolidation of management practices unfolded. The factory system became the paradigm for the organization of production in manufacturing, as mechanization became the paradigm for technology. The distinctive feature of the factory was the close monitoring and supervision of work ("factory discipline").

The factory system, at its beginning, contributed to reinforcing the trend towards the intensive utilization of unskilled and cheap labour. The analysis of Goldin and Sokoloff (for the US) has shown that early factories tended to make "disproportionate" use of women and children[76]. The use of this type of workforce was permitted both by an increased technical division of labour and by the managerial supervision of the work process allowed by the new system. Factories also brought about a consistent saving of time, by increasing throughput and facilitating machine and process coordination. Thus, technological and organizational changes interacted, mutually reinforcing each other. The key importance of a coherent transformation in the organization of production complementing the introduction of new techniques can be illustrated by contrasting the case of Paul and Wyatt with that of Arkwright. Paul and Wyatt's enterprise (a spinning factory) was an economic failure. The main determinant of this outcome was the incapacity of the two partners establish to a sound factory discipline, so they could not achieve the rate of throughput that would have permitted them to reach the break-even point.[77] Conversely, the reasons for Arkwright's success did not lie so much in the technical improvements he added to the Paul and

[75] Lazonick, *Competitive Advantage on the Shopfloor*, (Harvard 1990), p.84.
[76] Goldin and Sokoloff, "Women, children and industrialization".
[77] See Von Tunzelmann, "Time-saving technical change".

Wyatt's machine, as in his ability to implement opportune changes in work organization (above all in the securing of work discipline).

However, as there were technological alternatives, also organizational alternatives existed. In a complementary way, with historical studies of technology stressing the existence of a relatively wide set of technological opportunities, a recent strand of literature[78] has emphasized the weaknesses of the "orthodox" conceptualization of industrialization which considers rapid mechanization as synonymous of accelerated technological change and the latter going hand in hand with the spread of the factory system. A wide variety of ways of organizing production (artisan and cooperative workshops, "advanced forms" of putting out, etc.) was tried and many of them proved viable in adapting to changing technologies and changing market conditions, competing with the factory system for a long time, well into the industrial period.[79] Berg and Hudson, among others, have outlined the surprising technological and economic dynamism of the so-called "traditional sector":

> The classic textile innovations were all developed within a rural and artisan industry; the artisan metal trades developed skill-intensive hand processes, hand tools, and new malleable alloys. The wool textile sector moved to new products which reduced finishing times and revolutionized marketing. New forms of putting-out, wholesaling, retailing, credit and debt and artisan co-operation were devised as ways of retaining the essentials of older structures in the face of the new, more competitive and innovative environment. Customary practices evolved to match the needs of dynamic and market-oriented production.[80]

Indeed, the historical record shows that in a number of cases the new technologies were suitable to be employed in very different forms of the organization of production. Hills has shown, for example, that Arkwright's

[78] See among others Bruland and Smith, "Industrialization, steam power and economic historiography" and Sabel and Zeitlin, "Historical alternatives"
[79] See Berg, *Age of Manufactures*,pp. 199-233.
[80] M.Berg and P. Hudson "Rehabilitating the Industrial Revolution", *Economic History Review*, 45 (1992), p. 31.

water frame (an archetypal example of a factory machine) could have been easily adapted to domestic manufacture:

> The water frame could have been built in small units, placed in cottages and turned by hand. In other words, it could have been used like the jenny as a domestic spinning machine... By restricting the licence to units of a thousand spindles, it became economic only when these were erected in a water-power mill. This was a vital decision in the development of the textile industry and of the Industrial Revolution which never seems to have been recognized before.[81]

Even the use of a large and centralized power source, like the steam engine, was in some cases compatible with a decentralized putting-out system, as in the case of the "cottage factories" of the Coventry ribbon-weaving industry described by Marx:

> In the Coventry ribbon industry the experiment of "cottage factories" was a quite natural and spontaneous development. In the centre of the square surrounded by rows of cottages, an engine-house was built and the engine was connected by shafts with the looms of the cottages. In all cases, the power was hired out at so much per loom. The rent was payable weekly, whether the looms were working or not. Each cottage held from two to six looms; some belonged to the weaver, some were bought on credit, some were hired.[82]

For Marx, in the long run, the "cottage factories" could not compete with the rise of the factory system:

> The struggle between these cottage factories and the factory proper lasted over twelve years. It ended with the complete ruin of the 300 cottage factories.[83]

[81] Hills "Hargreaves, Arkwright and Crompton", p.123.
[82] K. Marx, *Capital: A Critique of Political Economy*, Vol I (1867, Penguin edn., Harmondsworth 1976), p. 589.
[83] K. Marx, *Capital*, p.589.

Subsequent historical research has shown that the reasons for the demise of the Coventry "cottage factories" lay elsewhere. In the early 1860s, as a consequence of free-trade developments, the Coventry silk industry was directly exposed to competition with French silk ribbons and soon it was driven out of the market. In the longer term, the entire Coventry silk trade, not only the "cottage factories", died.[84]

Another striking example of effective integration of new technologies and of new sources of power into an artisan structure of production is the case of the West Riding woollen industry. In this case, the final stages of the production process (fulling, scribbling and carding) were performed in "company mills" often powered by steam. These "company mills" were owned by partnerships of small clothiers, who sent their work to their own mill for final processing. The initial and more labour-intensive stages of the production process (spinning and weaving) continued to be conducted in clothiers' cottages. This form of industrial organization adopted in the 1830s and the 1840s proved to be rather successful and many "company mills" continued to exist well into the late nineteenth century.[85]

In many cases, the machine-breaking riots were a manifestation of workers' aversion to the factory system. Workers tended to favour forms of work organisation, which allowed them to maintain an autonomous control of the labour process. Hence in 1778-1780, the machine breakers did not destroy the spinning jennies of 24 spindles used in domestic production, but only the larger ones used in the factories.[86] The destruction of the power-looms in Lancashire in 1812 and 1826 represents another clear example of resistance to the factory system. Finally, in the Coventry silk trade, workers' resistance prevented the introduction of steam-powered factories. In 1831, there was a sporadic attempt to build a steam factory, but the building was immediately burnt down.[87] The steam engine

[84] See Lazonick, *Competive Advantage*, pp. 50-52 and Berg,*Age of Manufactures* p.229.
[85] P.Hudson "From manor to mill. The West Riding in transition" in M.Berg, P.Hudson and M. Sonescher (eds.), *Manufacture in Town and Country before the Factory*, (Cambridge 1983)
[86] Hobsbawm, "Machine breakers",.p. 11.
[87] Berg, *Age of manufactures*, p. 224.

was welcomed only from the late 1830s, when, by means of the organizational arrangement of the "cottage factories" described earlier, it was successfully integrated into the artisan system of production.

In most of the literature, these possibilities of accommodation of the new technologies in the context of customary relations of production have been unduly neglected. Historians have generally tended to consider the pattern of development characterized by rapid mechanization and the centralization of production in large-scale factories as inevitable. In this respect, the more recent historical literature has brought support to Sabel and Zeitlin's conceptualization of the Industrial Revolution. Sabel and Zeitlin consider that the process of industrialization can be better represented by means of a 'branching tree' metaphor. In this view, the branching points represent decisive "brief interludes of openness", characterized by a relatively wide variety of technological and organizational solutions. However, the existence of powerful self-reinforcing mechanisms tended to ensure that, in a relatively short span of time, a dominant "techno-economic" paradigm was established and industrial development tended to follow a very localized path. The pathway emerging from the branching points will be shaped by the distribution of economic and political power in society as well as by market forces and technological constraints. Furthermore, Sabel and Zeitlin hold that one of these historically crucial branching points ("industrial divides") coincides with the period of the Industrial Revolution. In this way, a more complex picture of the industrialization process emerges and what Mokyr calls the "political economy of technical change" must pay due attention to the social conflicts over *the direction* of technical and organizational changes

In order to identify the specific features of different industrialization paths, Sabel and Zeitlin introduce the mass/craft-flexible production dichotomy. Roughly speaking, mass production systems employ specialized-purpose machinery and unskilled labour to produce standardized goods. Conversely, in craft/flexible production skilled labour and flexible machinery are used to produce customized goods. It should be noted that craft/flexible production and mass production are ideal typical conceptualizations. They represent two extreme (theoretically

conceived) cases, the actual historical experiences being distributed along the spectrum closed by these two extremes.[88]

Our previous discussion of the pattern of technological and organizational changes during the British Industrial Revolution indicates the undertaking of an "industrialization trajectory" geared to mass-production techniques. Another interesting piece of evidence in this respect is contained in the work by Griffiths, Hunt and O'Brien.[89] On the basis of a data set containing patent and non patented innovations in the textile industry, they argue for the existence of a fundamental discontinuity in the pattern of technical change in the 1790s. Until that period, textile innovations were mainly aimed at quality improvements and product differentiation. Hence textile growth was mainly characterized by an expanding variety of output. From the 1790s, there was a marked shift in the direction of process innovations aimed at achieving factor-saving improvements. This documented change in the pattern of technical change (which coincides with the establishment of the set of technological heuristics outlined before) can be interpreted as indicating the timing of the drift towards mass production. Not accidentally, the last part of eighteenth century and the beginning of the nineteenth was also the period in which workers' resistance to technology reached its peak.

Putting together the various threads of our discussion, we may contend that the machine-breaking riots and other expressions of opposition to innovation in the British Industrial Revolution should be understood in terms of the conflict between the historical alternatives to industrialization outlined by Sabel and Zeitlin. What the machine breakers rejected was not the adoption of new technologies, but the specific path of industrialisation undertaken by the British economy. The point is strongly confirmed by the highly selective nature of machine-breaking actions, which seems to indicate that hostility was directed towards mass production technologies and not towards flexible production ones. Furthermore, as recent historical accounts such as Randall and Berg, have shown, assuming that workers' activities were informed by a model

[88] Sabel and Zeitlin "Historical alternatives", pp.174-176.
[89] T. Griffiths, P. Hunt and P. O'Brien,"Inventive activity in the British textile industry", *Journal of Economic History*, 52 (1992), pp. 881-906.

of political economy alternative to the one of *laissez-faire* capitalism is not far-fetched. In fact, we should take into account that we are dealing with groups of skilled workers endowed with a good deal of technical expertise grounded in their everyday experience of technology users. They were capable of a fairly accurate assessment of the benefits and losses due to innovation, not only for themselves but also for the local community as a whole. What I would add to the accounts of Berg and Randall is that the crucial component of the model of political economy of the labouring classes during the Industrial Revolution was the choice of a "smooth" transition to industrialization. The pattern of industrial development should have been based on the development of flexible/craft production technologies and on the continuous accumulation of labour skills. In this sense, the political economy of machine breakers is somewhat reminiscent of the notion of "appropriateness" of technology that can be found in some development literature.

There is an apparent contradiction between the arguments set out in this paper and the analysis of Broadberry.[90] Broadberry has provided a highly original interpretation of the long-term evolution of British manufacturing productivity in an international perspective. His account stresses the resilience of craft production methods in British industry, contrasting it with the early adoption of mass production techniques in the United States. Therefore, at first sight, Broadberry's assessment of the development of the British economy appears to be in stark contrast with the analysis presented here. However, this is not the case. Broadberry's observation of a prevalence of flexible production technologies in Britain relative to the United States is not in contrast with what has been asserted here. My suggested interpretation considers opposition to machinery as the expression of a conflict over the specific direction of industrialization which divided British society during the Industrial Revolution. In order to reconcile Broadberry's findings with my account, it should be assumed that the "machine-breakers" aimed at achieving the selection of a path of technological advance that was closer to the flexible/craft production end

[90] S. Broadberry, *Productivity Race*.

of the "spectrum" than that one which was historically undertaken. In this sense, it is worth noticing that Sabel and Zeitlin in their paper consider Britain as an "intermediate case" between the United States and France, with some industrial branches geared to mass production and others to craft/flexible production.[91] In fact, the argument I have developed in this paper is also fully consistent with comparative analysis of British and French industrialization. O'Brien and Keyder (1978) have argued that it is highly inappropriate to see the process of industrialization in France in terms of "retardation" with Britain, for France was just moving along a different path.[92] The path undertaken by France was characterized by a reduced emphasis on the role of the factory and a particular attention to product-based learning and the continuous development of skills.[93] In some sense, France's development path was quite close to the notional development path, which the "machine breakers" appeared to prefer. According to O'Brien and Keyder, when compared in terms of industrial growth performance achieved along the whole nineteenth century, France did better than Britain. Crafts has reexamined O'Brien and Keyder's findings and has concluded that their case is probably exaggerated and that Britain maintained a small edge in industrial productivity performance over France.[94] However, notwithstanding his reassessment, Crafts himself still finds O'Brien and Keyder's central argument valid. In the European context, the pattern of economic growth in Britain is rather atypical. The economic performance of French industry is indeed remarkable, especially when considerations of the overall economic and social costs of the industrialization process are brought into account. Conversely, one might observe that, in the longer term, Britain's development path did not yield a particularly outstanding economic performance in terms of industrial productivity growth.[95]

[91] Sabel and Zeitlin "Historical alternatives", pp.164-171.
[92] P. O' Brien and C. Keyder, *Economic Growth in Britain and in France, 1780-1914* (London, 1978)
[93] Von Tunzelmann, *Technology and Industrial Progress*, pp.393-394.
[94] N. Crafts "Economic growth in France and Britain, 1830-1910: a review of the evidence", *Journal of Economic History*, 55(1984), pp.29-67.
[95] N. Crafts, *British Economic Growth during the Industrial Revolution* (Oxford,1985), p. 88.