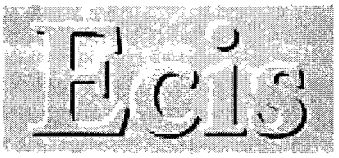
The "machine-breakers" and the industrial revolution



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The "Machine Breakers" and the Industrial Revolution*

by

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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 seemed to have been, at some point of time, smashed. John Kay's flying shuttle met a strong resistance and workers rioted against its introduction in 1758, 1785-7,1810-13 and 1822. Hargreaves'spinning jenny was attacked in several mobs (1767, 1769 and 1779). In 1779 there were also assaults against Arkwright-type of factories. The power loom was the target of the Lancashire Luddites in 1812.[1] Although this form of labour disturbances has been the subject of extensive historical investigation, there is still little consensus among historians about the exact nature and significance of this form of resistance to innovation

Recently Joel Mokyr (1990,1994a,1994b,1994c) has put forward a new interpretation of the machine-breaking riots, in particular of the Luddite outbreaks of 1811-12. According to Mokyr, the introduction of a new technology is generally resisted by those groups of society endowed with assets (in terms of capital equipment and 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 the resistance to the new technology will rely exclusively on non-market forces. Resistance to innovation can 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 process 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 stylized theoretical framework. Drawing mainly on Randall (1991), he finds a typical pattern of evolution in the resistance exerted by workers whose skills were superseded by the new technologies. Initially they tried, through a lengthy campaign of petitions to the Parliament, to obtain the enforcement of old regulations or the adoption of a new legislation that would have hampered the adoption of new technologies. The Parliament did not support their claims. Thus, in a second attempt, the workers resorted to machine-breaking activities. But also these attempts were unsuccessful (perhaps with the only exception of the Captain Swing riots), because of the strong repression by the government. 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 the political power in Britain was so much favorable to the innovators was a further advantage of Britain relative to the other European countries in the early stages of industrialization, which might help to explain the classical question "why Britain was first".

[1] See Mantoux (1961), p.208 and Berg (1985), pp. 260-263.

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. I do not produce any new findings but I simply compare and comment the existing literature. In this sense this paper is an exercise of analytical interpretation.

My main contention is that Mokyr's overall thesis is untenable. Although he is correct in pointing to the conflict between different groups in society 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 (1985) have referred to as "historical alternatives to industrialization", rather than, as Mokyr does, a conflict between the supporters of a progressive technological path and the vested interests favoring a stagnating status-quo. Furthermore, I argue that the resistance of the working class to the introduction of the 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 the historical accounts of the riots and on the 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 expands previous works of Berg and of Von Tunzelmann . Section 5 draws conclusions suggesting that the analysis of the machine-breaking riots can provide some illuminating insights on the nature of British industrialization.

2) THE HISTORICAL ANALYSIS OF "MACHINE-BREAKING": A SHORT OVERVIEW OF THE DEBATE.

Nowadays the word "Luddite" indicates a stubborn opposition to the adoption and diffusion of technological advances. Most often the word is used in a pejorative sense and conveys the idea of both a thoughtless and desperate action.[2] The common use of the word seems to evoke a compelling historical lesson. Attempts to stop or delay the diffusion of new technologies are both ill-conceived and ineffective. These attempts are deemed to focus on the wrong target ("the machine"), which is unduly seen as a vehicle of economic distress, instead of pointing to the necessary economic and social

[2] The Concise Oxford Dictionary (1982 edition) says: "Luddite: member of bands of English artisans (1811-1816) who raised riots for the destruction of machinery; person similarly engaged in seeking to obstruct progress". For a detailed analysis of the semantic evolution of the word see Linton (1992).

adaptations that can minimize the negative social and economic by-products of technological progress.[3]

The common usage of the word "Luddism" and "Luddites" is implicitly grounded in what we may call the "traditional" historical interpretation of the machine breaking riots. This interpretation is reminiscent of the debate "on the machinery question" which characterized the development of political economy in England in the period 1815-1848.[4] In particular, it echoes the position of those authors which favored the "unrestrained adoption" of new machinery. Those authors claimed that in a capitalist economy, powerful "compensation mechanisms" would have been able to assure both the complete re-absorption of technological unemployment generated by labour-saving innovations and a fair distribution of the benefits of technical progress. [5] Vivarelli (1995) has correctly pointed out that several factors can hamper or obstruct the working of the "compensation mechanisms", so that their efficacy cannot taken for granted but should be empirically assessed in any given case.

It is worth noting that also the major part of more recent literature on the machine-breaking activities[6] have more or less shown a more or less explicit belief in the validity of the classical "compensation theory". [7] The machine breaking riots, in what we may call the "traditional" interpretation,[8] are consequently seen as desperate attempt to halt the industrialization process. The disturbances were the spasmodic reaction of workers to economic hardship. However, 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". [9]

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".[10] 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:

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[3] For a quite similar remarks see Randall (1995), p.57.

[4] On the "machinery debate" see the exemplar account of Berg (1980).

[5] See Berg (1980). For an interpretive account of the classical "compensation theory" see Vivarelli (1995), chapter 3. Vivarelli' s analysis is particularly important because it shows that much of the current debate on technological unemployment is based on arguments analogues to the classical ones.

[6] For a useful concise account of the "machine breaking riots" I refer the reader to Rule (1986), pp. 348-378.

[7] See for example Ashton (1957), p.120.

[8] The works of Ashton (1957), Mantoux (1961) and Bythell (1969) can be considered as representative examples of the "traditional interpretation".

[9] Mantoux (1961), p. 408.

[10] See Bythell (1969), 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.

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. [11]

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 which was 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. [12]

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 the fear of the working class hostility to them.[13] 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 firsts not in line with the traditional interpretation. In their judgment the workers' reaction should not be regarded as totally 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 the Parliament, they resorted to direct action. Machine breaking was an attempt to enforce directly old customary rights. [14]

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 did not determine any marked deterioration 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 celebrated paper "The Machine Breakers",[15] Hobsbawm, one of the leading "pessimists", openly questioned the traditional interpretation and warned against accounts, which assume that the behavior of the early labour movement was simply a

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[11] Bythell (1969), p.271.

[12] "[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 (1969), p.271 (italics in the text)

[13] 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, 1969, 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.

[14] See Hammond and Hammond (1951).

[15] Hobsbawm (1964)

blind and irrational reaction to the pressure of a highly unfavorable economic condition. In most cases workers' actions were instead 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"[16] have found a hard time in explaining their persistence, their duration the difficulties of the authorities in repressing them, and the high degree of organization and self restraint shown by the "machine breakers".[17]

Hence, in order to avoid misjudgments, according to Hobsbawm, one has to take into account that the actions against machinery of the Industrial Revolution 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 organization of effective strikes, this pressure tactic was capable of achieving remarkable results.

Many authors have welcomed Hobsbawm's indication 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.[18] 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 of organizing effective "combinations" among workers. The second one 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 the 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.[19]

Thomis's account has been criticized by Rule and Randall.[20] In their view his attempt of 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

[16] Bythell (1969), p.180.
[17] 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,1969, p.200) .
[18] Thomis (1970).
[19] Thomis (1970), p.133.
[20] Rule (1986) and Randall (1991).

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 combined 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 workers to the introduction of new technologies.[21] In the rest of 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 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".[22] According to Thompson, the behaviors of the working class rested on an "industrial moral economy", which did not accept the rise of a not regulated 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. [23]

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

[21] Noble (1983), Randall (1991).
[22] Thompson (1963), p. 603.
[23] Thompson (1963), p.603.

living standards. [24] They were accustomed at capitalist labour relationships and they did not oppose to the market as a system of organizing production. They affirmed that the markets should operate within the stable set of limits established by custom. Hence, the continuous reference to "fair" or "unfair" prices. [25]

Another still open issue of debate is the degree of effectiveness of the 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.[26] 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, accepted to secure wage increases (Nottinghamshire), these wage-concessions lasted for a very short time span.[27]

In their more recent contributions, Rule and Randall[28] 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 made out to be".[29] 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 the one 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.[30] 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.[31] In this respect, Noble has suggested that in some cases one of the aims of machine breaking was simply to gain time and to achieve a slow introduction of the new technologies in the economic system, minimizing the possible negative economic and social consequences of a too rapid change.[32]

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[24] Rule (1986), p. 255.
[25] On the notion of "industrial moral economy" see Randall (1991)
[26] Bythell (1969).
[27] Thomis (1970), p.161.
[28] Rule (1986) and (1995). Randall (1991)
[29] Hobsbawm (1964), p.17.
[30] Hobsbawm and Rude' (1973). The case of the threshing machine undoubtedly deserves to be further investigated by the economists of technical change. The Captain Swing riots seem to have contributed to un-lock a system that was locked in a sub-optimal technological practice: "The reasons for the general sympathy with machine breaking was rather...that the Luddite mobs appeared as a sort of fortunate 'act of God' which alone, short of the unthinkable banning of machinery by law, could extricate all farmers from a situation in which they were forced against their better judgment" (Hobsbawm and Rude' p. 322)
[31] Randall (1991),pp. 82-83. See also Rule (1986),p.365.
[32] Noble (1983)

3) JOEL MOKYR AND THE POLITICAL ECONOMY OF TECHNICAL CHANGE

Mokyr has recently noticed that in most of the cases technological progress has a double-edged character.[33] 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[34] 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.[35] 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, machine-breaking to intimidate the would-be adopters of the new technology.[36]

Krusell and Rios-Rull have built a formal model aimed at capturing the main insights of Mokyr' s argumentation.[37] In their model, the final good is produced by a Cobb-Douglas technology in skilled and unskilled labour.[1] 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 to the introduction of the more productive technology t+1, because its adoption would completely depreciated 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.

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[33] See Mokyr (1990),Mokyr (1993), Mokyr (1994a), Mokyr (1994b), Mokyr (1994c)

[34] "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" (Mokyr, 1994c,p.564)

[35] In a later contribution (Mokyr 1994c), he admits the possibility of lock-in in an inferior technological solution. However he does not elaborate much further on that.

[36] 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. " (Habakkuk, 1967, p.125)

[37] Krusell and Rios-Rull (1996). It is important to note that Mokyr explicitly considers the model of Krusell and Rios-Rull as a good representation of his views. See Moyr (1994c), p.564.

The analytical framework elaborated by Mokyr and formalized by Krusell and Rios-Rull (which Mokyr has labeled "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 forms of non-market processes, and the struggle is fought on a multiple level. Thus a wide variety of resources can be mobilized into it. As a result it is very difficult to make an a priori assessment of the relative strength of the various social groups involved. However, if we take into account that the benefits of innovation usually accrue to a more widespread and heterogeneous set of agents than the losses and, because of the free rider problem, it is likely that 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 technological progressive societies have been such only for relatively short periods. The "political economy of technological change" explains why social attitudes favorable 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 his conceptualization to the case of British Industrial Revolution. In this way, he attempts to provide an innovative account of the machine-breaking riots.

For Mokyr, many technical advances of the Industrial Revolution displaced a considerable amount of labour skills. These labour skills were an important asset of small and strongly unionized group of workers (like the Yorkshire woolen 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, British Parliament had to examine a lot of petitions asking for enforcement of old quality regulations[38] 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, 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 in the Continent is a major factor explaining "why Britain was first".[39]

The economic and social policy of the British governments during the Industrial Revolution was dominated by great landowners and by large commercial and financial interests. In Mokyr' s view, they opted for a "technological *laissez-faire*" policy because they realized that resistance to the introduction of innovations would have favored British

[38] 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.
[39] Mokyr (1994b), pp. 34-35.

competitors undermining English economic and political leadership. However Mokyr acknowledges that private interests probably played the predominant role:

> The true motivation of the British elite [for supporting the innovations] probably had a more selfish cause. The Industrial Revolution in its first stages benefited the landlords as much as the industrialists, without making them assume any risk. The technological changes led to a sharp rise in the values of real estate throughout the industrializing regions and mining areas, and with the exception of the debate on the Corn Laws (which the landed interests won) there was little conflict between landed interest and economic interests created by the Industrial revolution. [40]

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 in a more general interpretation of the industrialization process in Britain.

Recent historical accounts show that Mokyr is substantially correct in analyzing the machine-breaking riots in terms of a conflict over technological choice. However, on closer scrutiny, his explanation neglects important aspects emerging from these 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 the workers, who saw the value of their labour skills being eroded by the introduction of new technologies, but it must be reminded that the machine breakers enjoyed a fairly widespread support, undoubtedly well beyond 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 much in Mokyr's representation of the machine breakers as an Olsonian lobby. The historical analysis of Randall (1991) and of Rule (1995) show that other motivations, besides the rational preservation of a self-interest were of key importance.[41]

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 a customary and well-functioning system of production. Their model of political economy "placed a premium on stability, regulation and custom"[42], 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 (1996), what Mokyr has in mind is a contrast between those who support the introduction of a better performing (more productive) technology, and those who favor the status quo. On the contrary, the evidence from the history of technology suggests instead that the most common case was the competition among several technological options and many of

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[40] Mokyr (1994a), pp.245-246

[41] "[I]nnovation was frequently met with resistance not merely from those in immedaite 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, 1991, p. 44)

[42] Randall (1991), p.227. For an appraisal of the key role played by customary practices in small craft economies see Sabel and Zeitlin (1985), pp. 152-154.

them were capable of generating sustained productivity increases. Thus, it is not appropriate to focus exclusively on the developments mechanized and capital intensive techniques, for also the performance of hand tools and small scale machinery was constantly improved.[43] Furthermore, recent work in the economics of technological change has pointed out that usually the performance of techniques is improved over time along not one but several dimensions.[44] 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.[45] 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. [46]

Thirdly, when considering the choice of technique, we should take into account the influence exerted by the need of eliciting workers' effort. Bowles[47] has formally analyzed choice of technique issues when factor productivities are not given but they are affected by factor prices, as in the efficiency wages hypothesis. In this case we have to take into account that the choice of techniques can have an impact on the position of the worker's reaction curve in the effort/wage space. 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). [48] Von Tunzelmann has outlined the central role played by the necessity of extracting workers' effort in the diffusion of machine-paced production in the textile industry during the 1830s and 1840s .[49] 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 the 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

[43] Berg (1980), p. 177 and Von Tunzelmann (1978), chap 7. In Ciccone (1997) the British Industrial Revolution is modeled as the interaction between a capital intensive "factory" sector and a "cottage" sector, producing the same good. Total factor productivity growth is increasing in both sectors, but it grows faster in the "factory" one. Interestingly enough, the model shows that the emergence of the "factory" production will be accompanied by a severe slow down in the growth of real wages.

[44] In the textile industry power driven technologies were generally more productive than hand technologies only for low quality yarns and cloths. See Von Tunzelmann (1978), chap 7.

[45] The literature on this issue is vast. See Cowan (1991) for an introduction to the most important issues.

[46] It is important to remark the pre-emptive character of many machine-breaking disturbances. See Randall (1991), p.150.

[47] See Bowles (1985) and Bowles (1989).

[48] See Bowles (1989), p. 72.

[49] Von Tunzelmann (1978), pp. 202-225.

workers. Lazonick (1990) contains also a discussion of choice of techniques issues in the cotton industry from the same perspective. This excursus into "radical" contributions illustrates the theoretical (and historical) relevance of a conflict on the choice of techniques of a different type from 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).

This last point is closely related to the debate between Marglin and Landes on the rise of factory production.[50] For Marglin, factory production, *in its very beginning,* did not enjoy of any *major* technological or organizational advantage over others form of industrial organization.[51] The historical record suggests that new technologies (including the steam engine) did not compel the adoption of any specific form of industrial organization, but they could have been used (and in many instances were indeed used) in many different contexts. The main reason behind the transition to factory production did not lie in its superior efficiency, but in the fact that, through supervision and the creation of a set of interdependent production tasks, it permitted the extraction of more effort per unit of labour time. Moreover, factory supervision drastically reduced the problem of embezzlement Landes has rebutted Marglin's thesis, maintaining that the technological imperative was decisive. The factory system was endowed with an efficiency advantage over the artisanal workshop and the puttying out system and market forces acted in such a way of selecting the most efficient organizational structure. In a very interesting paper, Clark has concluded that the scanty empirical evidence available is in favor of Marglin's thesis. [52]

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. More in detail, 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 of the British Industrial Revolution.

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[50] See Marglin (1974) and Landes (1986)

[51] The italics is used to stress the crucial "caveats" of Marglin's thesis.

[52] See Clark (1994). In the same paper Clark sets out a very ingenious explanation for the rise of factory system (which I do not subscribe). For him, labour markets were competitive, so the workers actually *chose* to work in the factory system. They did so because an "anomalous" structure of their preference set did not allow the maximization of their utility function in an autonomous way. In my view, the labour market during the Industrial Revolution (perhaps with the exception of the period of the Napoleonic wars) was characterized by an abundant ("unlimited" in the sense of Lewis) supply of labour, so it is more right to say that, in general, workers had no choice.

In the third step I tackle 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 the 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 (1975) 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. 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 have been in some way possible to guarantee better living standards to the working classes during the indutrialization process ? Von Tunzelmann (1985) has maintained that is the second counterfactual the really relevant one, because it is 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

In the early 1980s, Lindert and Williamson claimed to have definitely solved the factual dimension of the standard of living debate in favor of the optimists. [53] According to them, real wages were stationary until the 1820s and from 1820s to 1850s they increased of about 80 per cent. These results have been recently contested by Feinstein. In his view, Lindert and Williamson' s index of real wages contains serious flaws. Feinstein has produced an alternative index of real wages. His index shows between 1780s and 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.[54] 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 woolen cloth. [55]

I think that Von Tunzelmann's dismissal of the first counterfactual interrogative formulated by Hartwell and Engerman is correct. Industrialization *per se* has never been an issue of debate for the pessimists. The evidence suggests that industrial change *per se*

[53] Lindert and Williamson (1983)
[54] Feinstein (1998), pp. 649-650.
[55] Feinstein (1998), p.651.

was not an issue also for the working classes.[56] When technical innovations facilitated work, without reducing employment they were never resisted.[57] Berg (1980) has argued that the bulk of the "machinery debate" was on the economic and social implications of the specific *direction* of technical advances. [58] 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 crucial issue both for the standard of living debate and for our discussion. Von Tunzelmann has shown the historical viability of alternative (and more favorable to the working classes) growth paths during the period in question.[59] Notably, these alternative growth paths would have been less capital intensive than the actual one.

At this juncture, I suggest to take a further step and assume that capital accumulation (due to the localized nature of technological change) takes place around specific techniques, as it was suggested by David (1975). In this case, 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 (1997) has expanded the model proposed by David, suggesting that the use and refinement of specific techniques involves the complementary adoption of specific forms of work organisation. 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. [60]

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

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

[56] See for example the writings collected in Berg (1979).
[57] Randall (1991), p. 7.
[58] See Berg (1980) especially pp. 16-17 and p.76
[59] Von Tunzelmann uses a standard neoclassical growth model to identify the optimal growth path. Then he contrasts the optimal path with the actual path.
[60] See Coriat and Dosi (1998) for thorough discussion of the complex interplay between technological and organizational learning. The concept of techno-economic paradigm elaborated by Freeman and Perez (1988) is an attempt to capture the broad "consistency" of technological and management practices.

new and more abundant raw materials, in particular, the substitution of mineral for vegetable or animal substances. [61]

Further, for Landes, "the logic" of this complex of technical advances compelled the adoption of a new system of production, the factory system. [62]

Historical research has questioned the concomitance of these trends. Von Tunzelmann (1978) and others have shown that the adoption of steam powered machinery should be regarded as a much later phenomenon. Evans (1982) has emphasized the continued and widespread use of wood and timber until the mid-nineteenth century. Thus, 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. [63]

In his more recent works Von Tunzelmann (1994, 1995a, 1995b) has attempted to give a new account of the pattern of technical change in the British Industrial Revolution, using Dosi's paradigm/trajectory approach.[64] One of the main merits of this approach is to deal explicitly with the crucial issue of the direction of technical advances; a theme that was not appropriately tackled by Landes.[65] For Von Tunzelmann, the prevailing technological paradigm in manufacturing can be summarized under the heading of "mechanization". This means that the creation or refinement of mechanical contrivances was considered the privileged solution for "technical" solving problems arising in the course of the production process. In most of the cases, this amounted to substitute machines for human skills, and to convert the to-and-fro motions of human arms and feet into rotary motion.[66] In Dosi's approach, technological trajectories are generated by the interplay between the "autonomous"[67] drift of technology within the boundaries of the technological paradigm and a particular set of inducement factors of economic type. Economic inducement factors are likely to play a role in determining the specific direction of the technological trajectory when the paradigm is its emerging stage. Over time the heuristics get progressively established and technical advances become increasingly localized and irreversible.[68]

In the early phase of the Industrial Revolution, amalgamation of inducement factors with the internal logic of the technological paradigm generated a stable set of

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[61] Landes (1969), p. 41.

[62] Landes (1986), p. 615. This view is further restated in Landes (1993)

[63] See Bruland and Smith (1981). This point was also stressed by Marx in chapter XV of *Capital.*

[64] See Dosi (1982) and Dosi (1988).

[65] On the shortcomings of Landes's analysis of technical change see Bruland and Smith (1981) and Bruland (1982)

[66] Von Tunzelmann (1995a), p. 105.

[67] The "autonomous"drift of technology is the product of the "compulsive sequences" of solutions of technical bottlenecks described by Rosenberg (1977)

[68] See Dosi (1988), pp. 1142-1145. This is fully consistent with the analysis presented in David (1975) 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.

time-saving heuristics. [69] 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 (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.[70] It is important to note that these features are an indication of a productive system already geared to mass production.

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).[71] 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. [72]

Using data from Manufacturing Censuses, Goldin and Sokoloff (1982) 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 is correct to assume that a similar technological trajectory was unfolding in Britain.[73] This is also confirmed by accounts of single technological innovations. Bruland (1982) analyzes the cases of three important textile innovations and shows that bypassing the power of highly skilled groups of workers was the main target innovative efforts..[74] In chapter 15 of Volume I of *Capital,* Marx noticed three effects determined by the introduction of new machines on labour: 1)" labour diluition", that is substitution of skilled (mainly adult male) with unskilled labour (women and children), 2) prolonging of the working day (because new machinery was mainly used in the

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[69] 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 (1995b).

[70] Von Tunzelmann (1995a), p.116.

[71] This is also acknowledged by Von Tunzelmann (see Von Tunzelmann (1995b), p.3), although he assigns the predominant role to time-saving. Perhaps it is more correct to say that the two detained the same importance. It suffice here to report a quotation from Ure: "The constant aim and the tendency of every improvement in machinery is, in fact, to do away entirely with the labour of man, or to lessen its price by substituting the labour of women and children for that of grown-up men or of unskilled for that of skilled workmen" (Marx (1867), p. 558).

[72] Nicholas and Nicholas (1992)

[73] See Goldin and Sokoloff (1982), in particular p.742-743. In this respect, see also Habakkuk (1962), pp. 151-156.

[74] See also Berg (1985) and Randall (1991) for many other examples of innovations aimed at substituting adult male work for women and children. On the basis of data on literacy of the convicts deported to Australia Nicholas and Nicholas (1992) have argued for a generalized "deskilling" of the British workforce in this period.

factories), 3) intensification of work (speeding up of machinery made labourers work harder). Von Tunzelmann (1978) in his analysis of the development of the textile industry has confirmed the historical relevance of this part of Marx's analysis. In addition, it must be noted that the development of a pattern of technical change which made intensive use of cheap categories of labour became characteristic not only of factory production but also of the emergence of the "sweated system", that is urban outwork employing intensively very low-wage labour.[75] Furthermore, "deskilling" technical advances quite often determined an intensification of labour (mainly achieved by means of a speeding up of the production process).

Freeman and Perez (1988) in their theory of long waves have made use of the notion of "techno-economic" paradigm. A "techno-economic" paradigm can be defined as the prevailing set of technological and managerial practices which are shaping economic behaviors in a specific period. In other words, a "techno-economic" paradigm embodies both a "technological vision" akin to Dosi's technological paradigm and a managerial vision indicating the ideal form of productive organization. One of the main feature of a "techno-economic" paradigm is that it prescribes the intensive use of a "key-factor" with the following characteristics: i) clearly perceived low (or even falling) relative cost; ii) almost apparent unlimited supply over long periods; iii) clear potential for incorporation in many products or processes throughout the economic system. [76] Freeman and Perez indicate cotton and pig iron as the key factors of the classical period of the British Industrial Revolution (which they appropriately label as "early mechanisation Kondratiev"). [77] Given the reconstruction of the pattern of technical change presented above, my impression is that Freeman and Perez's identification of the "key factor" is not appropriate. The fundamental "key factor" in this historical phase was doubtless unskilled labour. Unskilled labour seems, in fact, to fit much better than cotton (a consumption good) and pig iron (an input which can be hardly considered of pervasive use in the first phase of the Industrial Revolution) in Freeman and Perez's definition of the "key factor". As we have already seen, the recent findings of Feinstein suggest that real wages were stagnating until the early 1830s and after then underwent a moderate increase (less then 30 per cent of their 1778/82 level) until the late 1850s. Whatever might be our hypothesis about productivity trends in the period, it is probably correct to assume that productivity growth is likely to have outstripped real wages growth, even if not by a large amount. For these reasons, unskilled labour enjoyed of a considerable cost advantage when compared with other inputs. Furthermore, both "classical" and historians have been inclined to regard England as an economy endowed with an abundant ("unlimited" using the expression of W.A. Lewis) supply of "unskilled" labour.[78] In addition one might observe that labour-surplus models have been widely used to account for the early phase of the industrialization process in Britain. What I stress here is the role played by technical changes in facilitating the mobilization of the workforce from agricultural and domestic to modern industrial sectors.

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[75] See Berg (1985) p.146-49. On the growth of the "sweated system" Marx noticed: "...nowhere do we find a more shameful squandering of human labour-power for the most despicable purposes than in England, the land of Machinery " (Marx (1867), p. 345)

[76] Freeman and Perez (1988)

[77] See Freeman and Perez (1988), table 3.1

[78] See Habakkuk (1962), chap. V.

In many cases machine breaking riots were an expression of workers' resistance against 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.

> [H]ighly 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.[79]

Labour "dilution" driven by technical change can be better illustrated by means of the following simple example.[80] Assume that a group of workers, because they possess a particular skill, are able to command a "customary" wage $w = \overline{w} + c$, where $\overline{w}$ is the subsistence wage that one of these skilled workers can earn when he is not employed in this activity and c is the cost that the capitalist must pay in order to recruit and train a new worker so that he can perform the production activity of the skilled workers. One can conceive the introduction of a new technology which will leave the level of output per worker hour (and all the other relevant inputs) unaltered, but which will reduce the level of c to c_1 ($c_1 < c$), allowing the substitution of the skilled worker with cheaper labour. The impact of the technique will be to reduce the wages of the skilled workers to the new level $w_1 = \overline{w} + c_1$. The innovation has the *only* effect of driving the "customary wage" commanded by the skilled worker towards the subsistence level and of redistributing a part of the employment rent to the capitalist. It is evident that in this case it will be convenient for the employer to introduce the new technique, and to the workers to resist the introduction of the innovation. Recent estimates by Crafts and Harley have shown a very modest growth of productivity in the early phases of the industrialization process.[81] This finding has created some perplexities because the same period is considered a phase of particularly rapid technological change.[82] Note that the pattern of technical described in our example may help to provide an explanation of the paradox.

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 allow them to exert some control on the supply of labour. This aspect is aptly emphasized by Rule:

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[79] Von Tunzelmann (1995a), p. 111

[80] The example is taken from Bowles (1989)

[81] See Crafts and Harley (1992), pp. 718.

[82] Besides the traditional accounts of the period by historians of technology, the recent quantitative analysis of Sullivan (1989) has revealed a sharp acceleration of patenting starting from the late 1750s.

Manufacturing artisans....largely accepted the idea that bargaining was 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.* [83]

Two of 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 to the power loom, instead, should be seen more as a form of resistance against the factory work.

Randall (1991) 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 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 formulated also 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 resistance of the English working class seemed to be more aimed at re-directing the development of technical advances in particular direction rather than at stopping it.

In the woollen workers' case a number of proposals asked for 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 in order for it to be smoothly integrated into the traditional organization of production.[84]

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 taxation 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.[85] The revenue of the tax should have been used to constitute a relief fund for the displaced workers.[86]

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[83] Rule (1995), p.186 [italics mine]
[84] Randall (1991), p. 73-74.
[85] Berg (1980), p. 242.
[86] Thompson (1963), p. 575..

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 the working class hostility to the specific direction taken by technical change during the Industrial Revolution. In the terms of the paradigm/trajectory approach, the actual issue at stake was the assessment of the space of technological opportunities and the choice of a specific direction in this space.[87] The machine-breaking riots and other expressions of resistance 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 resistance has to be exerted in the early phases of the development of a new technology.[88] Finally, the highly symbolic power of machine destruction stressed by Noble (1983) can be seen as revealing the intention of exerting a fundamental shock on the "visionary ideas"[89] governing the design of machinery and, in this way, conditioning the prevailing technological heuristics.

The availability of a relatively wide "spectrum of techniques" in this 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...[90]

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.[91] Another important innovation was the "pendulum loom" invented by John Sadler which was capable of raising substantially the productivity of hand weaving.[92]

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[87] Dosi himself has remarked the powerful influence that industrial conflict may exert in the shaping of technological trajectories: "[P]atterns of industrial and social conflict are likely to operate within the process of selection of new technological paradigms, both as negative criteria (which possible developments to exclude) and as positive criteria (which technologies to select)" (Dosi (1982), p. 155).

[88] "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 (1991), p.150)

[89] Sabel and Zeitlin (1985), p. 134.

[90] Habakkuk (1967), p.29 See also Berg (1985), p. 220.

[91] Von Tunzelmann (1978), pp.201-202.

[92] Berg (1980), p. 267. Samuel (1977) cites several examples in which 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" (Samuel (1977), p.28)

It is worth noting that in some cases workers'resistance was highly effective and it succeeded in shaping the direction of technical advances in a favorable way. The most striking example for the textile industry is the case of the spinning mule The original mule was invented by Crompton in 1779. It was not power-driven and it was explicitly designed for being employed in cottage production.[93] 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.[94]

Successive technical developments allowed the use of the spinning mule in the 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 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". [95] 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....[M]uch 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 exceptional circumstances. [96]

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.[97] 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 with the formation of a stable set of technological heuristics, a process of consolidation of management practices unfolded. As Coriat and Dosi (1998) have argued, the two processes should be best seen in terms of co-evolution (new technologies

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[93] See Von Tunzelmann (1995a), p.110. See also Hills (1979).
[94] See Chapman (1972), p.21.
[95] See Rule (1986), p.270.
[96] Catling (1970), p. 149.
[97] It is important to note that technological opportunities would have allowed the design of mules for weaker operatives (women and youths) but it was preferred to raise the productivity of adult male spinners, by increasing the number of spindles per mule. See Lazonick (1990), p.84.

permit the implementation of new forms of work organization, and new forms of work organization, in turn, affect the development of new technologies).

The factory system became the paradigm for the organization of production in manufacturing, as mechanization became the paradigm for technology.[98] The distinctive feature of the factory was the close monitoring and supervision of work. ("factory discipline"). It is worth noting that as a form of production organization the factory in some industrial branches (e.g. in wool spinning) was adopted without any technical changes, that is organizational change preceded technical innovation.[99]

The factory system, at its beginning, contributed to reinforce 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 [100]. 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 consistent saving of time, by increasing throughput and facilitating machine and process coordination. Thus technological and organizational changes interacted mutually reinforcing each other.[101] 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 the one 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 of establishing a sound factory discipline, so they could not achieve the rate of throughput that would have permitted to reach the break even point.[102] Conversely, the reasons for Arkwright's success did not lie so much in the technical improvements he added to the Paul and Wyatt's machine,[103] but in his ability to implement opportune changes in work organization (above all in the securing of work discipline).[104]

However, as there were technological alternatives, also organizational alternatives existed. In a complementary way with historical studies of technology stressing the existence of relatively wide set of technological opportunities, a recent strand of literature[105] has emphasized the weaknesses of the "orthodox" conceptualization of industrialization[106] which considers rapid mechanization as a synonymous of accelerated technological change and the latter going hand to hand with the spread of the factory system. A wide variety of ways of organizing production (artisan and cooperative workshops, "advanced forms" of puttying out, etc.) was experimented and many of them proved viable in adapting to changing technologies and changing market conditions,

[98] Von Tunzelmann (1995a), p.127.
[99] See Marglin (1974).
[100] Goldin and Sokoloff (1982).
[101] Von Tunzelmann (1995a), p. 128.
[102] See Von Tunzelmann (1995b).
[103] See Mantoux (1961), p. 213.
[104] See Marglin (1974).
[105] See among others Samuel (1977), Bruland and Smith (1981), Berg (1985) and Sabel and Zeitlin (1985)
[106] Landes (1986).

competing with the factory system for a long time into the industrial period. [107]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, wholesailing, 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.[108]

Indeed, the historical record shows that in a number of cases the new technologies were suitable of being employed both in very different forms of organization of production. Hills (1979) has shown, for example, that Arkwright's water frame (an archetypal example of a factory machine) could have been easily adapted to domestic manufacture:

> [T]he 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 license to units of a thousands of 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 be recognized before.[109]

Even the use of a large and centralized power source, like the steam engine, was in some cases compatible with a decentralized puttying-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. [110]

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. [111]

Subsequent historical research has shown that the reasons for the demise of the Coventry "cottage factories" were others. In the early 1860s, as a consequence of free trade developments, the Coventry silk industry was directly exposed to competition with

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[107] See Berg (1985), pp. 199-233 and Berg (1994).
[108] Berg and Hudson (1992), p. 31.
[109] Hills (1979), p.123.
[110] Marx (1867), p. 589.
[111] Marx (1867), p.589.

the French silk ribbons and soon it was driven out of the market. In the longer term, the entire Coventry silk trade demised not only the "cottage factories".[112]

Another striking example of effective integration of new technologies and of new source of power into an artisan structure of production is the case of West Riding woollen industry. In this case the final stages of the production process (fulling, scribbling and carding) where performed in "company mills" often powered by steam. These "company mills" were owned by partnerships of small clothiers, who send 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 effectuated in clothiers' cottages. This form of industrial organization adopted in 1830s and 1840s proved to be rather successful and many "company mills" continued to exist well into the late nineteenth century.[113]

In many cases the machine-breaking riots were a manifestation of workers' aversion to the factory system. Workers tended to privilege 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.[114] 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.[115] The steam engine was welcomed only from the late 1830s, when, by means of the organizational arrangement of the "cottage factories" described earlier, it was possible to integrate it in 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. However, the more recent historical literature has questioned this interpretation. In this respect, the more recent historical literature has brought support to Sabel and Zeitlin's conceptualization of the Industrial Revolution. [116] Sabel and Zeitlin consider that the process of industrialization can be better represented by means of 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 tend to assure that, in a relatively short span of time, a dominant "techno-economic" paradigm will be established and industrial development will tend 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

[112] See Lazonick (1990), pp. 50-52 and Berg (1985), p.229.
[113] See Hudson (1983).
[114] Hobsbawm(1964),p.11
[115] Berg (1985), p. 224.
[116] Sabel and Zeitlin (1985)

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 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 individuate 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.[117]

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 of Griffiths, Hunt and O'Brien (1992). On the basis of a data set containing patent and non patented innovations in the textile industry, they argue 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 casually, 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 resistance to innovation of the British Industrial Revoultion should be understood in terms of the conflict between the historical alternatives to industrialization outlined by Sabel and Zeitlin. What the machine breakers refused 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 (1991) and Berg (1980) have shown, assuming that workers' activities were informed by a model 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 fairly accurate assessment of the benefits and

[117] Sabel and Zeitlin (1985), pp.174-176.

losses due to the innovation, not only for the workers 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 a 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 (1997). Broadberry has provided a highly original interpretation of the long-term evolution of British manufacturing productivity in international perspective based on the David (1975)'s model to which I have also referred to. 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 reconstruction 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 contented here. My suggested interpretation considers resistance to machinery as the expression of a contrast 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 advances that was closer to the flexible/craft production end of the "spectrum" than the 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.[118] In fact, the argument I have developed is also fully consistent with comparative analysis of British and French industrialization. O'Brien and Keyder (1978) have argued that 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. 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.[119] 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 (1984) has reexamined O'Brien and Keyder's findings and has concluded that their case is probably exaggerated and that Britain detained a small edge in industrial productivity performance over France. However, notwithstanding his reassessment, Crafts himself still finds O'Brien and Keyder's central argument valid. The economic performance of French industry is indeed remarkable, especially when considerations on the overall economic

[118] Sabel and Zeitlin (1985), pp.164-171.
[119] Von Tunzelmann (1995a), pp.393-394.

and social costs of the industrialization process are brought into account.[120] Conversely, one might observe that, in the longer term, Britain 's development path did not yield a particularly outstanding performance in industrial productivity growth.[121]

5) CONCLUDING REMARKS

Stimulated by some recent historical literature,[122] this paper has tried to set out a speculative interpretation of the nature and significance of the "machine-breaking riots" which took place during the British Industrial Revolution. Basically, what is suggested is that resistance to innovation can be best understood when it is placed in the context of the conflict between mass production and flexible specialization outlined by Sabel and Zeitlin.

In this concluding section I would like to point out that from the account of machine-breaking riots presented some interesting implications for our understanding of British transition to industrialization can be drawn.

Together with their work of re-estimation of British economic growth during the Industrial Revolution, Crafts and Harley have set out also a new macroeconomic account of the period.[123] According to Crafts and Harley, the British economy was characterized by a limited supply side potential for economic growth. Technological innovations were not pervasive, but highly concentrated in few modernized sectors.[124] Some of them like the steam engine needed a rather long period of improvement and refinement before being widely adopted. Thus the impact of innovations on productivity growth was displayed with considerable delays. This would explain the relatively slow economic growth of the period in question. Even if concentrated in few sectors, industrial transformation triggered a large process of structural change which ultimately led Britain to become the "workshop of the world". By virtue of the adoption and refinement of new technologies, modernized industrial sectors were capable of capturing increasing shares of foreign markets. However, it should be born in mind, that in the late eighteenth and in the early nineteenth centuries the growth of these sectors meant a larger employment of population in industry compared with other countries without the attainment of particularly high productivity levels.[125]

On the role of technical change in the industrialization process, Crafts (1995) observes that radical innovations are endowed with a strong stochastic component. Thus, it is not far-fetched to assume that the initial "spurt" of the industrialization in Britain was favored by some luckier draws in the pool of innovations than the ones of other countries like France. Technological breakthroughs were subsequently refined by stream of micro-innovations and gradually generated productivity increases in the modern sectors. This

[120] See O'Brien and Keyder (1978), pp.185-188.
[121] Crafts (1985), p. 88.
[122] Especially Randall (1991) and Rule (1995)
[123] See Crafts (1985), Crafts and Harley (1992) and Crafts (1995).

[125] Crafts (1985), pp. 65-67.

view of industrialization, based on the distinction between radical and incremental innovations, is also endorsed by Mokyr (1990), although he downplays the stochastic exogenous element by noticing that England enjoyed of "comparative advantage" in incremental innovations. However, as Von Tunzelmann (1995b) has aptly noted, this view of technological change neglects important features of the innovation process, above all the fundamental issue of the direction of technological advances. The paradigm/trajectory approach seems preferable, because it deals explicitly with this question.

At the outset of a new "techno-economic" paradigm, a variety of development paths are open. Political and social struggles will emerge on the direction to be undertaken, as suggested by Freeman and Perez (1988). The final trajectory will be by and large shaped by the very outcome of these social conflicts. In this paper, I have argued that this was exactly the case of the British Industrial Revolution. A conflict about different industrialization alternatives divided British society. A pattern of technological change and organizational transformation with a strong emphasis on mechanisation and process innovations, factory system and mass production emerged. It is worth noting that the pattern indicated in this paper may well explain the coexistence of slow growth with large and rapid structural change and the long term resilience of Britain in pattern of specialization in unskilled labour intensive sectors remarked in Crafts and Harley 's macro account.

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