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When Should Workers Embrace or Resist New Technology?

Abstract. The question of how workers might respond to new technologies has lurked behind many debates on the subject. It has not been posed directly, in part because of concerns about the determinism of asking about the effects of a technology. A preliminary is to set aside these concerns by showing that effects can be identified without determinism. The main argument is that technologies can be assessed on six dimensions: intended or unintended effects; direct and indirect effects; degree of reconstitution in use; immanence; degree of success; and degree of discontinuity with the past. These dimensions can then be used to pose questions about any one technology. Three illustrations suggest how such questions can be posed in concrete conditions. Technologies can be challenged so that alternatives to extant systems of work organization can be considered.

The 2016 World Economic Forum defined its theme as being 'mastering the fourth industrial revolution', meaning the impact of digital, biological and other technologies on jobs and organizations (*Guardian*, 19/1/2016). This reflects what Holtgrewe (2014) neatly terms the rise of 'new new technologies', such as those promising 'human enhancement' through devices as varied as exoskeletons and implants to improve hearing (see 'Human Enhancement and the Future of Work', at www.britac.ac.uk/policy/human-enhancement.cfm). Such developments raise large questions about the social costs and benefits of apparently dazzling technologies, as illustrated by evidence of the highly exploitative working conditions in factories producing the new artefacts (Chan et al., 2013). The present paper makes one very specific contribution: to lay out some dimensions which help workers and trade unions to consider whether to embrace or resist a new technology.

The issue has not to date been specified in this way. We thus need to begin by briefly locating the contribution in debates on new technology and justifying the question. Secondly, the logic of speaking of a technology that then has effects on workers needs to be specified. One does not need to be a determinist to accept that technologies have effects, and we follow scholars who start from such a view. Technologies are adopted for many reasons, but once in existence they have implications. Our purpose is to offer some means to think about what those implications are. We do so from the point of view of 'workers', that is, people in subordinate positions in the division of labour; the effects of technology for capital, such as improving productivity, are not the concern. We also look at these issues in relation to workers in the sphere of production, and not their position in society as a whole, as

consumers or citizens. Thirdly, we identify and explain the dimensions. Finally, we offer three examples of different kinds of technologies to illustrate how they can be used. The purpose is to offer tools of analysis and not substantive answers; as Hyman (2012: 155) puts it, the task of the academic is not to produce 'recipe books for workers' but the 'elaboration of the right questions'.

Justifying the Question: Debates on Technical Change

If we think of how workers have come to terms with new technology, there has been a consistent tendency to focus on the implications and to bargain about the pay and other implications of new kinds of job. The technology itself has rarely been central, reflecting of course the fact that managements have tended to involve workers and unions only very late in the process of technical change. A wealth of research, embracing long-term responses to changes in work organization (Hyman and Elger, 1981), new technology agreements in the 1970s (Williams and Steward, 1985), and European Framework Agreements (Prosser, 2011) supports this assessment.

Workers would not find much help from academics, whose dominant approach is to side-step our question. A major series of studies on technical change, synthesized by Freeman and Louçã (2001), looks at the causes rather than the effects of technology, In relation to effects all these authors do is to quote Dickens's famous lines about the best of times and the worst of times and say, 'the fundamental thing is to choose' (p. 372). This is true but not very informative. Many other scholars, including those addressing the philosophy of technology (e.g. Ferré, 1995; Pitt, 2000) also eschew this question.

The dominant view is that the effects of technologies are socially shaped. In the words of Bradley et al. (2000: 109) it is a myth that science and technology necessarily improve the experience of work. This view is neatly captured in a celebrated piece by Sabel and Zeitlin (1985: 176): 'it is the politics', they concluded, 'and not the immanent characteristics of the technologies that will decide how new machines are designed'. This conclusion stemmed from a review of the history of technical change that challenged what they saw as the conventional or narrow view, which they traced back to Marx and Adam Smith. That view saw technical progress as development along a single path defined by efficiency. In place of this view, they identified examples of craft modes rather than mass production and argued that the eventual decline of many of these modes reflected political choices and not historical inevitability.

If we followed the 'narrow' view, our question would not be worth posing, as technical change would be inevitable and out of workers' hands. Yet Sabel and Zeitlin destroy only a view that technology advances along a single path. They seem to conflate two arguments which have been carefully distinguished by G. A. Cohen in relation to the forces of production in general, which Cohen rightly takes as embracing not merely tools, but also knowledge, and other non-material aspects of technology. The erroneous view, implicit in what Sabel and Zeitlin criticize, is that 'there is a tendency for the productive forces to develop autonomously'; that is, the forces develop independently of the relations of production. The correct view says that 'there is an autonomous tendency for the productive forces to develop' (Cohen and Kymlicka, 1988: 177). This subtle distinction makes a big difference. The tendency exists within the forces; it does so because capitalism, in contrast to other modes of production is driven by a drive for accumulation. But how far it is called into existence empirically will depend on many circumstances (see further Cohen, 1988: 21-5). For our purposes, we need to say only that technology has a tendency to develop, but the ways in which is does so are shaped by many other economic and political forces.

To further delimit the task, consider Cohen's discussion of the connections between the material forces of production and the social relations in which they are embedded (Cohen, 1978: 28-62). He argues extensively that the distinction between forces and relations makes sense, and that the forces tend to develop in the sense of improvement. This matters because he gives well-articulated grounds for arguing that technology as part of the forces of production operates asocially (Cohen, 1978: 28-62). That is, there are tendencies which are independent of and causally prior to what happens at the level of social relations. The tendencies themselves exist because of capitalism's drive for accumulation. The forces of production thus cannot remain static.

We see this argument as offering grounding for what we discuss, in that the argument establishes why technologies can be said to have effects. But this is only the grounding, and we do not discuss the point further. In essence, workers have some interests in the development of the forces of production, because this potentially creates more and better jobs (Edwards et al., 2006) but there is a also a tendency in capitalism towards the use of the technology to reduce workers' control of the process of production or otherwise enhance capital's interests.

In short, technical progress is driven by the development of the forces of production, there are real potential benefits in terms of the kinds of goods and services available, and these forces

have effects on society. Discussing how to respond to those effects is a meaningful endeavour. Two leading scholars underline the ability of technologies to have effects on workplace relations that reflect the technologies themselves. Orlikowski (1992: 400, emphasis added) has identified, and ascribed to, a 'soft' determinism in which 'technology is posited as an *external force* having impacts, but where these impacts are moderated by human actors and organizational contexts'. She later draws on Actor Network Theory and its view that artefacts as well as people can be 'actants'. She argues for example that, when a company issued all its managers with mobile phones, the phones were not just a means to communicate; they changed the very nature of the communication itself (Orlikowski, 2007). Wajcman (2006: 783) similarly points to the 'constitutive power of tools, techniques and objects to materialize social, political and economic arrangements'. Secondly, we can assume that capitalism has the additional tendency to deploy technologies in ways that may harm workers. Given these two high level facts, how can workers think about whether or not to embrace a technological innovation?

Technological Dimensions

In this section, we first identify a set of dimensions that characterize technologies. In relation to what a technology is, we accept that there is no sharp distinction between technologies and wider processes of innovation. It is convenient, however, to focus on concrete things, as we think that the argument would extend to innovations in general. After identifying dimensions, we spell out what they mean for workers.

The Dimensions

Orlikowski (1992) usefully identifies three dimensions. They are as follows.

- *Intended or unintended effects*. Some technologies are introduced with clear ends in view. The users of early steam engines had the objective of pumping water from mines, the intended effect. An unintended but reasonably specific effect would be that deeper mines could be worked. Less specific effects might include difficulties of ventilation in such mines. These difficulties then set the stage for the development of other technologies. They do not call them forth directly. They are a force of production and have to be put into effect through social processes. In this case, were people aware of a stock of knowledge that might be applied to ventilation systems? If they were, how would they assess the costs of finding a solution to the ventilation problem, and how might they evaluate different solutions to it?

- *Direct or indirect effects*. The above are examples of direct effects. Orlikowski's example of an indirect effect is a computer system designed to improve financial systems which has the indirect effect of reaffirming wider procedures in accountancy to do with cost control and the authority of budgets and numbers. This idea can be extended to embrace how pervasive a technology is in terms of its overall impact on the economic system. Some technologies have specific applications while others such as ICTs are extremely pervasive.
- *The degree to which a technology is reconstituted in use.* A simple appliance such as a phone, Orlikowski says, does not change when we use it. By contrast, she gives the example of a tunnel for the supply of water. It was designed for a certain level of flow, but demand was lower than expected with the result that the tunnel was not fully used. The lack of water allowed gases to collect within the tunnel, and there was a significant explosion of methane. In this example, the technology of the tunnel does not change; it is the *extent* of its use that altered. But reconstitution can also mean, we would argue, that the *nature and application* of the technology alter. A conventional phone is not reconstituted in use, since all that can be done with it is to make calls. A smart phone is more likely to be reconstituted because it has broader and more flexible properties. The idea of reconstitution is, however, key.

These dimensions require some explication. In relation to *intentionality*, there are cases of clearly intended effects. The Davy safety lamp, discussed below, was designed to prevent methane explosions in coal mines. But situations are rarely this clear-cut. As we will see, some scholars think that coal owners also had other ends in view. Intentions will not necessarily be stated explicitly. And some intentions may not be clear in the minds of designers. This is especially true in the case of discontinuous technological change where, as discussed below, it is difficult to see what the indirect effects could be. The new technology studies of the 1980s are full of examples of uncertainty as to what a given technology might do.

That said, the more specific and narrow is the intent, the more easy is it to measure effects against what was intended. It is also possible, however, to chart emergent unintended consequences of a technology and then to consider what the effects have been. This is clearly easier *ex post* than *ex ante* but it is still possible to identify more or less desired paths that seemed to be opened up by a technology, for example whether or not to have nuclear power and if so what kinds of reactor are safer than others.

There is a strong link with the dimension of *reconstitution* here, for there may be unintended effects as people constitute a technology in new ways. Some reconstitution involves finding specific ways to operate a given technology. The literature is full of ways in which workers can subvert a potential effect (e.g.Russell, 2009).

In terms of technologies with *direct or indirect* effects, clear answers are most easily given the more that effects are direct only. Yet many technologies have effects that are indirect in at least two senses. Firstly, they affect workers who are not themselves subject to the technology, for example where an assembly line is accompanied by changes to the work of people in ancillary operations. Secondly, effects may contribute to wider organizational arrangements, as in the example given by Orlikowski. The more that there are such effects, the more complex the issue of how to respond will be.

These categories require additions. This need can be illustrated by the celebrated 'Marglin debate' on the origins of the factory system. Foreshadowing the Sabel and Zeitlin (1985) critique of technical progress as driven by efficiency, Marglin (1976) argued that factories were intended to give a role in the production process for the capitalist, who would otherwise be redundant. The value of the categories is that they help to locate the structure of an argument. In this case, Marglin claims the outcome (an enhanced role for the capitalist) as an intended and direct effect. He would presumably accept that the technology of the factory was then reconstituted in use, as capitalists learned how they could adapt and improve it.

The historical evidence shows that Marglin's argument was far too extreme. Yet those who re-assert an efficiency argument(Landes, 1986) disconnect the factory from its context and reduce to zero the potential effects of the factory on the relative power of capital and labour. In other words, Marglin's argument for intentional and direct effects was incorrect, but when we allow for unintended and indirect effects it is plausible to argue that the factory constituted one means by which capital was able to assert its role in the production process, albeit with other sets of effects such as the growth of a class of wage labourers with the ability to subvert capitalist discipline.

Some of these differences can be captured in Orlikowski's categories. Suppose that the capitalist builds a factory with the intent of using water power to speed the production of cotton. The successful mill will probably have unintended effects. Some can be captured in terms of the direct or indirect category. A direct and unintended effect could be improved transport systems to take the increased supply of cotton to market. Yet these categories do not

capture the whole story. They do not ask the fundamental question of what it is about a technology that produces an effect. What is the character of a cotton mill that has the potential to cause effects?

We thus need to introduce a fourth aspect.

> *The immanence of the effect*, meaning what is inscribed in the technology. Cohen (1988) gives the example of an army with groups of riflemen. Suppose that a machine gun is invented that calls for three men to operate it. It is natural to organize them in teams of three, a result which is strongly immanent in the technology. It may also, Cohen says, be natural to organize the three so that one has authority over the others, a result that we see as less strongly immanent but reasonably directly a result of the technology. In the case of a factory, once a number of machines is organized in one place, it is likely that different tasks will be identified and that different people will undertake them. There will also be issues of co-ordination, which is likely to call into existence the position of overseers. And so on. Certain technologies either require or strongly imply certain forms of social organization.

Heilbroner (1994 [1967]) in his early statement of a determinist view of the effects of technology essentially took a strong view on immanence. For him, large-scale production called forth a need for co-ordination and management of the process. But a great deal turns on how we define co-ordination and management. These terms can relate to the *technical* division of labour in the sense that an activity has to be carried out. But this sense is often conflated with the *social* division of labour such as the emergence of a class of overseers and managers. In principle, co-ordination could be secured by rotating the task between different people. It was not an immanent feature of the technology that a separate class of overseer exist. Similarly, the archetypical nineteenth century cotton factory had a division of labour defined by skill, age, and gender among other things. In short, are the effects strongly implied within the technology? Or are they only possibilities with which the technology may permit or encourage? Or, between these positions, is there an elective affinity between a technology and certain outcomes? To elaborate on this last possibility, an elective affinity means a situation in which there is a presumption of a linkage, within a certain social context. Thus large-scale production surely made it likely that a separate group of co-ordinators would emerge; that is, there was an elective affinity here. In the context of eighteenth century English society, it would also have appeared natural that these people were men, though this effect is less inscribed in the technology itself than is the rise of a group of any kind.

Immanence matters because the more that an effect is inscribed in the technology, the more the social choice is one of 'take it or leave it'. Where effects are less immanent, there is more space to moderate any negative effects. Immanence is clearly related to constitution in use, but the two are different. Immanence pertains to what is in the technology; how the nature of the physical world enables or limits what the technology can do. Constitution relates to the many non-technically-defined things that might be done with it. In Orlikowski's example of the tunnel carrying water, immanent features would include the need to have a class of worker able to maintain and repair the tunnel; the effects that arose from lower levels of use than planned reflected the economic context and not the technology itself.

A fifth dimension concerns the success of a technology. Marglin tended to assume that capitalist factories have their desired effects; yet history is littered with examples of technologies that fail to work or that are quickly superseded by others. We thus need to add:

> *the degree of success of the technology in meeting its aims*. Success is often assumed because the history of technology, as of other things, is written by the victors. But failure, or the degree of success, clearly affects any impacts that a technology may have. Debates in the 1980s on new computer technologies, for example, often assumed more dramatic effects than in fact occurred. They took what was immanent, for example the ability to count key strokes per minute, and assumed that it was managerially desirable in particular contexts to use this ability.

Now, the previous dimensions can be considered to measure what they claim to measure, that is, ways in which technologies themselves vary. Many aspects of success, by contrast, depend on social processes such as the use of advertising to promote the use of products. But success is not independent of the technology itself. Consider the competition between direct and indirect current as a means of electricity supply. There is an argument that the victory of the latter depended on the marketing and other skills of those who promoted it. But it is also the case that the limitations of direct current in relation to such things as the cost of transmission are inherent in the technology and hence that success is to a degree shaped by this fact as well as social shaping.

Unsuccessful technologies clearly do not have effects in practice. But they could still have potential benefits for workers. When, for example, computer control of machinery was being introduced, there was available a record-and-playback system which was a possible alternative to the CNC machines that were in fact deployed (Noble, 1979). The former might in principle have retained some of the craft workers' control of the work process that was lost

when CNC became dominant. To identify the implications of technologies thus entails establishing their technical attributes and the conditions under which they might be put into operation. If positive answers to both questions can be provided, at least in principle, then progressive capabilities have been identified, at least with respect to certain actors, in this case craft workers.

The dimension of success is important for two reasons. Firstly, if we expect a technology to fail we can be complacent about any effects. Secondly, if companies argue that a technology is not feasible but workers can show that it is viable, then workers may have a case to argue for its introduction.

Finally, and drawing here on the literature on the economics of innovation (Nelson and Winter, 1982), we need to consider the *degree of discontinuity* between a technology and what went before. Some technologies are largely incremental in nature. None the less, we can say, at least with hindsight, that some technologies open up new areas. Those in genetics would be an example. The more discontinuous a technology is, the more unknown its potential effects will be, and the harder it will be to assess its progressiveness.

Discontinuity raises the greatest challenges for analysis. Uncertainty is an essential feature of innovation, and this in turn means that potential effects are hard to discern. Discontinuity lies behind the other aspects of technology, making assessments in relation to each of them difficult. In some cases effects can be discerned only after a technology has been introduced, and here any identification of progressiveness is possible only *ex post*. The more discontinuous a technology is compared to what went before, and the wider are the social ramifications, the more difficult it is to put boundaries round a technology and thus consider how to respond to it. Yet not all technologies are so broad in nature, and more specific and focused ones can be addressed more readily.

We have, then, taken up three dimensions already identified by Orlikowski, together with one, discontinuity, widely discussed in the innovation literature. The other two, immanence and success, have emerged from debates about social shaping, specifically and respectively whether *features* of technologies are inherent in them and whether the *results* of these features are inevitable.

Implications for workers

In relation to intended and unintended effects, workers might need to distinguish further between the stated and unstated aspects of the former. Managements may intend a technology

to challenge extant job controls but are unlikely to make this explicit. It would be necessary to try to establish whether there were such unstated aims so as to respond appropriately. As for unintended effects, it may be possible to think through what these might be, either by considering what a technology could do or by looking at similar technologies in other settings. Workers' experience at the point of production may well generate insights not available to the designers of a technology (Kusterer, 1978) and thus permit development that is progressive from the workers' point of view. Similar considerations apply to direct and indirect effects.

As for reconstitution, the more that a technology is capable of reconstitution in use, the more possible it will be to moderate its negative effects or draw out the positive effects. An example in relation to negative effects is the well-known fact that the performance monitoring aspects of ICTs, such as counting computer key strokes, are often not deployed. This may be because first-line managers see no purpose in the data, or wish to evaluate workers on broader criteria. In this case, it is possible to use the resulting space to negotiate informally as to how, if at all, monitoring data are to be used. It is also well-known, by contrast, that call centres are often tightly regulated in terms of metrics such as average call times. Opportunities for reconstitution are here limited, which will in turn shape the ways in which workers might respond to the technology. As for positive reconstitution, the workplace sociology literature contains a mass of examples of ways in which workers amend formal rules to find new ways of working. Thinking in terms of reconstitution may help to capture such scattered practice.

As with direct effects, the *immanence* dimension is simplest where we can say that an effect follows directly from the technology. Continuous process technologies in industries such as oil refineries and chemicals plants require round-the-clock working. This in turn requires some form of shift work, with well-known effects on sleep patterns and workers' social life. Even the classic study aiming to undermine technological determinism (Gallie, 1978) in fact stressed this feature of work. But just how the shifts were organized was much less immanent. Specific variations could embrace 8 or 12 hour shifts or the frequency of the cycle on which shifts rotated through days and nights. Larger variations could embrace other aspects that are often seen as set by the technology but which are not strongly immanent. Thus shift working is often associated with male workers, particularly in process industries that have a masculine image. But we know that in sectors such as health care women often work shifts, and much of the work in continuous process plants entails the monitoring of

machinery rather than ‘male’ activities entailing physical strength. In short, the technical and the social division of labour can be analytically separated. The more that the division of labour is socially defined, the less immanent are the implications. To give a small example, we have studied shift working factories where workers were able to choose the shift pattern (here, 12-hour shifts). In circumstances where the same pattern was imposed, there might well be more discontent about it, but here workers’ active preferences moderated such effects. It is not the working of 12-hour shifts that has necessary effects, but how these shifts are embedded in a social organization (Wright and Edwards, 1998).

We also need to address the question of effects on different sorts of worker in different respects. People have multiple interests which may be affected differentially. In a classic study, Reid (1976) dissects the effects of steam power in small factories in nineteenth century Birmingham. He shows that it had broadly negative effects in relation to workers’ ability to control their own working time but positive ones in terms of greater earnings. Workers themselves might be able to make the relevant trade-offs, or one might find some groups of workers who made a judgement of progressiveness and others who disagreed. By looking at it in this way, we cannot give an answer *in toto*, but we can say who took particular views and perhaps explain why. In this example, it is plausible, for example, that younger workers were more favourable to the new technology than were older ones. We can then say that it was progressive for them and, in principle, chart the balance between them and other groups.

In Reid’s case we can say that workers had interests in wages, in control of working time, and in independence from managerial authority. Different parts of these interests will come to the surface at different times, and the re-organization of production discussed by Reid was one time when the interests surfaced and needed to be addressed. We can in other words consider what is progressive with respect to certain interests even if these interests are not brought to the surface.

Examples

We now offer three examples which illustrate the combined effects of these dimensions. They are chosen to capture different aspects of technology and to highlight themes from the dimensions. The first example is the Davy lamp. It is chosen because it was a very specific artefact that can be discussed in reasonably contained ways. It has none the less inspired some strongly contrasting accounts of its effects, and we argue that the dimensions help to make sense of these accounts. The second example is a form of lean production. It is clearly

far more than an artefact, being a complex of technical and social features, and we show how the dimensions apply to cases of this kind. Finally, we discuss 'Industrie 4.0' as an example of a contemporary series of 'new new technologies' (Holtgrewe, 2014) which some have hailed as representing a new industrial revolution (Marsh, 2012).

The Davy lamp

The Davy safety lamp, invented in 1815, for use in mines was a technical advance because, unlike previous lamps with a naked flame, it did not ignite explosive gases notably methane. A conventional Whiggish view of technical progress says that it was simply an improvement, in reducing the dangers of explosions. 'The introduction of the lamp had an immediate effect, decreasing the number of fatalities per million tons of coal produced enormously and also increased the amount of coal produced as it allowed miners to mine deeper seams of coal' (Royal Institution, at www.rigb.org/our-history/iconic-objects/iconic-objects.../davy-lamp**,** accessed 1/2/2016). The alternative view, laid out by Albury and Schwartz (1982), challenged this in several respects. In terms of the origins of the technology, the lamp was not the only device available, and it was socially selected; George Stephenson for example claimed to have invented a similar device earlier than Davy. In terms of effects, it was used by coal owners in dusty or deep mines that were formerly inaccessible; as a result, the rate of accidents in fact rose, and the technology was of questionable value to miners.

A more grounded view makes the following points. Firstly, the direct causal powers of the lamp related only to mines subject to methane, and not to mines as a whole. Data on overall accident statistics do not test the effect of the lamp. Secondly, mine safety in fact improved, largely as a result of better ventilation which was itself in part the result of new legislative requirements (Nichols, 1997). If we are interested in the causal powers of the Davy lamp with respect to mine safety, we might have to conclude that these were rather weak. But if we place it in the context of other technologies such as ventilation there is a more complex set of relationships at work. These are neatly summarized by Hair: a system of government-imposed inspections

> was necessary not only to force the owners to do what had not obviously been in their economic interest to do but also to induce them to do what, without state and legislative backing, they would most likely never have been able to do: discipline a traditionally unruly labour force in strict, tedious and often wage-reducing cautionary procedures (Hair, 1968: 560).

Government inspection, we would argue, responded to developments, including the Davy lamp, of the forces of production which permitted larger, deeper, and more complex mines. Such mines entailed employment of more workers and put the industry in the spotlight when disasters happened. The government was under pressure to act. The government could in principle have supported autocratic employers rather than legislating to control them. The fact that governments in the *laisser-faire* Britain of the nineteenth century did indeed act against the express wants of employers says something about what was necessary to maintain a functioning capitalist order: in the language of Offe and Ronge (1982), governments were balancing the demands of capital accumulation and of the legitimation of the system (see for more on the specifics of the British case Fox, 1985). As Hair stresses, state intervention had the, probably unintended, effect of leading employers to change the system of work organization. The result was a change in the organization of the labour process that entailed a rationalization and systematization of the work process. This last aspect, as with the case of steam power in Birmingham (Reid, 1976), had mixed effects from a worker's point of view.

The relevant artefacts here had causal powers such as reducing explosions. Their concrete effects depended on several other processes such as legislation. This is also a very good example of the ways in which the relations of production or indeed that classic part of the superstructure, the state, had effects on the forces of production. In the case of coal mines, legislation on safety and government inspections encouraged more bureaucratized systems of managing the forces of production that artefacts such as the Davy lamp promoted. Similarly, legislation on working hours in factories favoured some forms of development, notably of the larger and more mechanized factories where labour costs were a relatively small proportion of total costs, over more labour-intensive factories. Legislation led to developments that would probably not have occurred without it, or might have occurred more slowly.

In terms of our dimensions, two of them, *immanence* and the extent to which a technology can be *reconstituted*, reflect the character of technology itself. In this case, the implications in relation to both were tightly defined: the lamp reduced the chance of explosions but it had few other implications in terms of the division of labour, and it could not be reconstituted to any significant degree. We can also say that the lamp was *successful*. It thus had reasonably clear *direct* and *intended* effects. The lamp had a high level of *continuity* with prior efforts to improve mine safety, as with Stephenson's claims, and Albury and Schwartz (1982) are correct to stress that it did not emerge exogenously. The dispute about its wider role can then be seen as to do with *indirect* and *unintended* effects, notably in allowing deeper mines to be

worked. The line illustrated by Albury and Schwartz is one that says that there are indirect effects which may not be intended explicitly but which none the less have a strong affinity with the desires of capitalists. We have argued that the evidence does not sustain such an interpretation, and that use of the dimensions helps us to disentangle and assess arguments about technologies.

The conclusion for our overall, question, then, is that the direct and intended effects of the lamp in certain kinds of coal mine were probably beneficial from a workers' point of view. It may have contributed, along with many other factors, to mining in new conditions, but its effects here were swamped by wider arguments about ventilation, arguments that were successful because of the way in which the British state acted. In such a context, embracing new technologies, as a means to sustain the development of the industry and to improve working conditions in it, probably made a degree of sense. That said, the health and other risks of coal mining remained huge, and here we come to the limit of the dimensions and enter what Sabel and Zeitlin (1985) rightly see as political territory.

Lean production at NUMMI

We look at lean production specifically in relation to the celebrated case of the NUMMI plant in California which opened in 1984 because it has been presented as a case where this technology can in fact benefit workers (Adler, 1992, 1993 2007).[1] For Adler, knowledge at NUMMI was socialized through a process of organizational learning. This was based on a highly organized and disciplined production process wherein specific requirements were carefully identified. It was then possible to standardize knowledge and to give workers the power to act on this knowledge with work methods and standards being, according to Adler (1993), determined by work teams. The explicit contrast is Volvo's facility in Uddevalla, Sweden. Here, Taylorized systems were replaced with team assembly and long cycle times. This meant, again according to Adler, that workers lacked the means to identify and address issues in the production process. NUMMI was more productive, and it also brought benefits to workers in terms of what Adler calls job quality.

If we look at NUMMI itself, the evidence is much less convincing. Three indicators of job quality are offered: absence levels, rates of participation in a suggestion scheme, and job satisfaction measured through company surveys. The first to our knowledge is never used in

[1] The plant closed in 2010. Any technical progressiveness does not ensure long-term economic survival.

studies of job quality, for a low absence level can reflect coercion rather than satisfaction. On the second, there is also evidence that participation is imposed rather than voluntary (Graham, 1995). The third does not represent independent evidence, and satisfaction conflates job quality and employee expectations. NUMMI workers may have been satisfied in the light of prior experience, but this does not mean that they were empowered in any substantive sense. Nor does Adler explain what 'determining' work processes means, in a context of very short cycle times and closely specified work rules. Not surprisingly, therefore, 'organizational learning' is not clearly defined and not evidenced. It would appear that there was a tightly disciplined process over which production engineers had close control. Knowledge of the process certainly existed, but the term 'organizational' implies that the knowledge is shared by all as a collective property. There is no evidence that NUMMI achieved this.

A study comparing NUMMI and two other advanced manufacturing plants develops this argument (Klein, 1991). Compared to previous auto industry work systems, NUMMI clearly reduced individual workers' autonomy through such things as the reduction of buffers. Adler would see this as outweighed by the collective control of the production process. But, firstly, that is a political and not a scientific judgement. Workers may well have grounds for wanting individual autonomy which cannot be dismissed. Secondly, Klein contrasts NUMMI's system for changes proposed by workers, which required extensive processes of approval, with those at another factory, where team members had a much greater range of freedom. 'Socialization' was contained within a managerial process rather than being collective sharing on a basis of equality.

It is also the case, as Adler recognizes, that NUMMI was not typical of lean production plants: he acknowledges critiques in terms of management by stress, and says that this may apply elsewhere but not here. Subsequent research on lean production systems, informed by much deeper evidence than seems to have been available at NUMMI, confirms that jobs generally remain very tightly defined and that any learning is far from being a collective property (e.g. Elger and Smith, 2005).

With this information, we can turn to the dimensions of technology, leaving to one side the issue of success, for lean production clearly works as a technology. In terms of *reconstitution*, there is little evidence that workers were able to reshape the technology, and the general picture was one of incremental change within a paradigm. *Intentionality* is always hard to identify, though it does seem clear that lean production's exponents in Japan were intent on

driving out waste and making the technical processes more transparent and controllable. What they intended in terms of a social division of labour is less clear. It is reasonable to argue that standardization of work tasks and a tightly prescribed social division of labour were strongly implicit. Thus the fact that lean production proved to be readily internationally transferable suggests that it was a package that could be implemented in many places. This is in contrast to Volvo's systems, which were highly context-dependent and were, indeed, not transferred to the company's operations outside Sweden. This point also addresses the *immanence* of the technology. A tightly disciplined organization of production is entailed in it, as reflected in a focus on driving out waste and achieving a highly controlled production process. This generally suggests that jobs will have limited autonomy, thought it is possible that in some contexts autonomy can be greater.

As for *direct and indirect effects*, the most interesting feature here is the nature of the latter. Some came about through concrete relations between lean production firms and other firms, most notably through the control of the supply chain and requirements on suppliers to deliver within the demands of just-in-time production. Some of these indirect effects were immanent in the technology, in that, to run a lean production process, it is necessary to organize systems outside the focal factory. Others, notably the shifting of cost and risk to supplying firms, were not. Other indirect effects arose through the copying of lean production by other firms.

In relation to *discontinuity*, lean production falls in the middle of the range. It transformed production processes and extended from manufacturing to services. But it was and is within a family of technologies concerned with the mass production of products, and was much more continuous than many other technologies.

Finally, turning to the *for whom?* question, lean production clearly benefited the firms practising it. For supplier firms, there were benefits in terms of a market for their products but costs in relation to the bearing of risk; there was also differentiation in that some had the capacity to take on the new system while others did not. As Graham (1995) argues, workers gained in comparison to life in more traditional plants in respect of a cleaner and more planned and controlled work environment. Though there was no necessary reason why their collective voice should have been weakened, in practice lean production implied a best practice approach which tended to rule out alternative views.

If we then imagine a group of workers faced with a lean production plant, they have a check-list of issues to consider. Some of these are about the technology itself. What are the hard

constraints that are likely to generate a particular division of labour? What does it imply about the intensity of working, and what can be done about this in terms of rest breaks and job rotation? To the extent that a technology is re-constituted in use and that immanent effects are weak, the greater are the opportunities to affect how it works in practice. Other questions concern the relations of production. Volvo workers were able to use the institutional regimes of their companies to influence many aspects of the production process such as work assignments and discipline. What opportunities are presented in terms of aspects of the regime, including such things as corporate reputation, to shape its organization?

Industrie 4.0

We now turn to ‘Industrie 4.0’ (also known as ‘the internet of things’, ‘advanced manufacturing’ or ‘the factory of the future’) as an example of a contemporary series of ‘new new technologies’ (Holtgrewe, 2014) which some have hailed as representing a new industrial revolution (Marsh, 2012; Davies, 2015) to underline the value of the framework. The term is being applied to a new phase in the digitization of manufacturing as a result of the growing use of sensors, the expansion of wireless communication and networks, the deployment of increasingly intelligent robots and use of artificial intelligence, the emergence of new forms of human-machine interaction through touch interfaces and augmented-reality systems, as well as the development of 'big data' analytics. The 4.0 designation is meant to signify a new stage in the evolution of manufacturing systems following from the first industrial revolution of steam power and mechanical manufacturing, through the second based on electric-powered mass production, and the third based on electronics and information technology (Davies, 2015). It has been widely promoted by the German Government and by firms including Bosch and Siemens (e.g. www.industry.siemens.com/topics/global/en/digital...suite/.../default.aspx) .

A first point turns on whether Industrie 4.0 is mere hype. The introduction of these technologies does appear to have a high element of discontinuity. Working groups established by the German government that coined the concept see these technologies as disruptive innovations in the area of production. However, their introduction is very much in an incipient stage so that much of the discussion about their impact is highly speculative (see for example comments by the representative from IG Metall in http://www.industriall-union.org/industry-40-the-industrial-revolution-happening-now or EU policy documents such

as Smit, 2016).. In terms of our dimension of success, there appear to be strong economic and political arguments for its adoption. Economically, it offers a means of accumulation for capital, hence perhaps the eagerness of some firms for it. Politically, as the above-cited sources show, it offers a vision of a manufacturing renaissance and a means to prevent the exodus of jobs from the advanced economies. As for immanence, some accounts identify positive implications that are strongly based in the technology. Thus some explicitly 'worker-centric' studies such as those of Facts4Workers (http://facts4workers.eu/project/key-facts) focus on the details of the technical division of labour and issues such as the improved availability of materials (e.g Denner et al., 2015). Others identify possibilities of automation such as reductions to physical strain of tasks and easing the work of maintenance technicians through preventive maintenance (e.g. Russman et al., 2015). On the other hand the technology enables more intense control and monitoring of workers' performance (http://www.euractiv.com/section/innovation-industry/news/germany-s-industry-4-0-in-full-swing-despite-dissent-from-unions/). One immanent characteristic of the technology is the ability to conjure up more lifelike virtual scenarios. Virtual industrialization for example could be used to make a lifelike design of a new plant before it is built, making it technically possible for workers to have a voice in the design of their work environment. Whether this technical possibility is realised however a social issue. Much of the focus of the discussion on Industrie 4.0 is on the changing skills needs and the requirement to retrain workers with the explicit recognition that low skilled workers in manufacturing industries are likely to lose out.

Effects of the above kind, if they indeed occur, are direct. But there may also be wider indirect effects. In relation to people working with Industrie 4.0 itself, there is a paradox in that it is presented as flexible and adaptive, and yet it appears as a fully configured system with linkages between the parts being defined by information technology. It may offer empowerment at the level of the specific task along with a reduced ability to shape the wider contours of the system. Moreover precarious work is predicted to increase (http://www.industriall-union.org/industry-40-the-industrial-revolution-happening-now). In relation to workers affected more generally, at least two issues stand out. The first is the familiar one of the supply chain. What kinds of jobs will be created in firms that supply Industrie 4.0 firms and will pressures for performance that already exist in modern supply chains be exacerbated? Secondly, there appear to be increasing numbers of 'crowd workers', that is those who work through online platforms such as Amazon's Mechanical Turk. Such

people may well enjoy individual autonomy and even creativity, but in a context of chronic insecurity. New technologies may thus be changing the structure of jobs and thus the balance of costs and benefits.

Finally, what of reconstitution? Manufacturing flexibility appears to be one of the benefits of Industrie 4.0 suggesting possible high levels of reconstitution. Claims about skills and flexibility invite workers to ask just what sorts of skill are in fact being offered, who will bear the cost of the reskilling, and how much flexibility they have. This would mean a collective discussion about how tasks are combined into jobs, and how far jobs are defined in terms of teams rather than individual workers and 'retraining'. In relation to crowd workers, there is some evidence that they have become active in organizing against the individualization and low wages that were associated with the system's early incarnations (e.g. *Financial Times*, 3/11/2014: www.ft.com/cms/s/0/2c23a880-5df3-11e4-bc04-00144feabdc0.html). Identifying the characteristics of technologies and their potential effects through our dimensions may be one way of promoting such efforts.

Conclusions

Looking at technologies in terms of the six proposed dimensions has three main uses. Firstly, in terms of overall analysis, it permits the clarification of some debates about the uses and effects of technologies. We have for example identified the structure of the arguments of scholars such as Adler (2007), Marglin (1976) and Albury and Schwartz (1982), and used relevant examples such as the Davy lamp and NUMMI; it is the possible to see what is in dispute and why. Underpinning this approach is an application and extension of 'soft determinism' (Orlikowski, 1992), informed in turn by Cohen's (1978) analysis of the connections between the forces and the relations of production.

Secondly, analysts of technology can use the dimensions to characterize specific cases. This is a challenging task. We have for example stressed that identifying indirect and unintended effects is difficult and that this is particularly hard where a technology is discontinuous with respect to previous generations: how deeply a technology affects an industry, and how widely it affects other industries, may not be known for some time. The dimensions are thus useful in seeing the boundaries of an analysis. As Armstrong (1988) demonstrated in relation to debates about de-skilling, many studies drew conclusions about long-term and system-wide developments from short-term studies often at the level of a workplace. The studies were not

wrong, but they neglected indirect and unintended effects. We have presented three contrasting examples, but the test is whether the dimensions are useful in other cases.

Thirdly, workers and unions can use the dimensions to consider how to respond to new technologies. A key here is to engage early in the process, that is before a technology becomes fixed, or in our terms before its immanent effects are finalized. The purpose here is that new forces of production contain potential benefits for workers, but these benefits have to be realized in the twin senses that people are aware of them and that the benefits are actualized. Industrie 4.0 for example presents itself as having the capacity to empower workers. We have offered, using the lean production example, a checklist that workers might use in trying to activate this capacity. If they are able to do so, the positive aspects of technical change may be more developed in the future than has often been the case in the long history of workers' engagement with new technology.

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