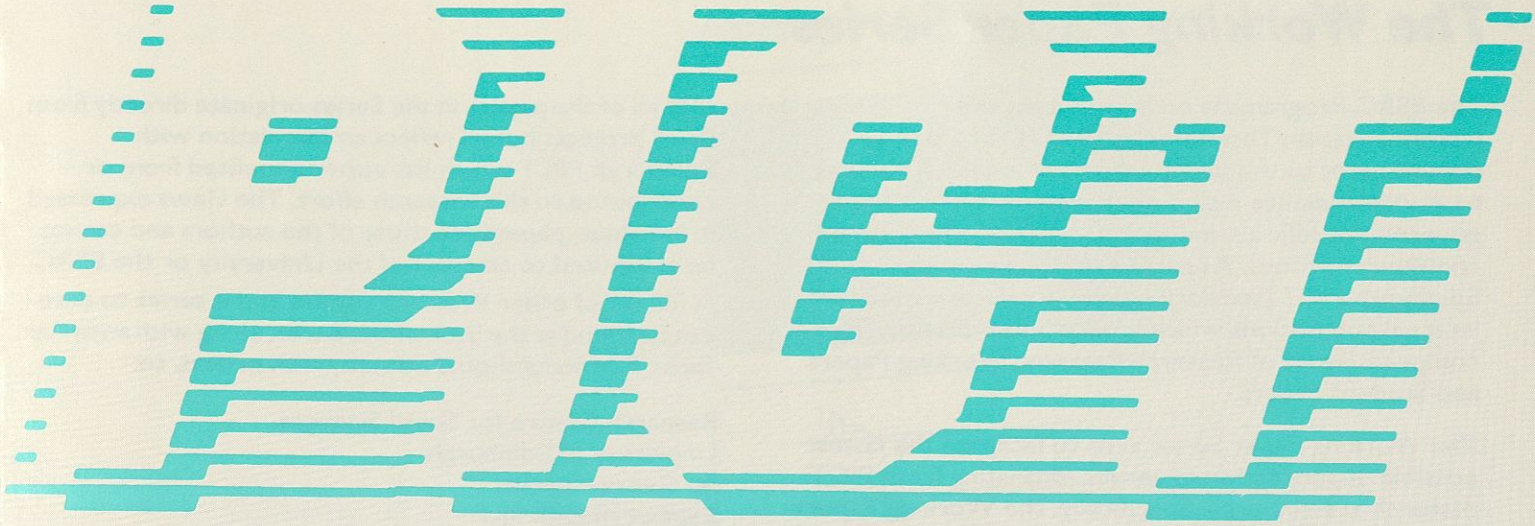

PROGRAMME ON INFORMATION & COMMUNICATION TECHNOLOGIES

Working Paper Series 3

OPENING THE BLACK BOX AND CLOSING IT BEHIND YOU: ON MICROSOCIOLOGY IN THE SOCIAL ANALYSIS OF TECHNOLOGY

Robin Williams and Stewart Russell

UNIVERSITY OF EDINBURGH

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OPENING THE BLACK BOX AND CLOSING IT BEHIND YOU: ON MICROSOCIOLOGY IN THE SOCIAL ANALYSIS OF TECHNOLOGY

Stewart Russell & Robin Williams *

This paper explores the problems in developing an analysis of technology that gives attention to both the complex detail of technological activity and broader social and economic influences. It examines the work of a group who have applied perspectives from the sociology of scientific knowledge to develop a claimed 'new sociology of technology'. The starting point of their analysis of technological development is the action and interaction between technologists and other individuals and groups directly involved. Criticisms of this 'micro-sociological' approach include the drawing of undue parallels between scientific and technological activities, and the extrapolation from micro-level activities eg of technological communities to analyse phenomena at a broader societal level. Empirical work from this group is contrasted with studies that start from analysis of the structural context and move towards the fine detail of development. Case-studies by the authors in the field of energy technology, the regulation of technological hazards and industrial process technologies are used to highlight the need for developed theories of broad social processes including the role of the state, its relationship with social interests and of class relationships in production. Some elements of a theoretical model are outlined that could yield an integrated explanation of influences at a structural level as well as a detailed local level.

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INTRODUCTION

Within the broad project of understanding the social shaping of technology, there have been a number of contributions recently from writers coming from the sociology of scientific knowledge. They bring with them approaches and concepts which have been developed for understanding the detailed actions of scientific communities and which are rooted in ethnomethodology, symbolic interactionism, or a similar form of 'micro-sociology' - variants on an action paradigm. In this paper we examine the analyses and theoretical claims of some of these writers - particularly Law, Latour, Callon, Pinch and Bijker. Though there are significant differences in their work, we see them as having much common ground, and indeed see in their collaboration an attempt to assert their basic approach as paradigmatic for a new 'sociology of technology'(1).

We find their recent work on technology valuable in many respects - in particular for the richness of their detailed accounts of the processes of technological change, and their openness to its complexity. However, they reject theoretical and substantive work which deals with broader social structures and processes. For them, the effects and very existence of 'macro-structures' can only be explained by extrapolation from micro- processes of interaction between individual social actors. Society, and their analysis of society, is constructed from the bottom upwards; the 'macro' is in effect reduced to the 'micro'. We feel that this approach is mistaken and unnecessary.

Our starting point is rather different. We have been analysing ways in which broader social structures, economic forces and political processes have shaped the overall development of technologies. We began with a critique of 'asocial' analyses of technology, which see technological development as socially neutral, accidental or governed by an inner, technical logic, and of 'social-determinist' analyses which sees technology as a mere epiphenomenon, a simple reflection of economic forces or social interests. We therefore sought to develop an account which did justice to the complex and often contradictory forces patterning technological development.

Like the action sociologists, we recognise the need for an adequate way of handling the detail of processes of technological development and

implementation. We too want to overcome the dualism between macro and micro level explanations. However, in response to the action paradigm of the micro-sociologists, we find ourselves in the position of having to reassert the importance of the macro, and to argue the need for several different levels of analysis of the social systems within which technological development is situated, and for concepts and methods appropriate to each. We contend that an understanding of broader structures and processes is necessary, both as a level of explanation per se of the general characteristics of a society's technology, and also as essential for a full explanation of detailed actions and outcomes, and how they are fundamentally shaped by their context. We argue further that it is possible to reconcile the macro and micro without collapsing one into the other: to have different forms of analysis which are nonetheless consistent. We point to existing theoretical frameworks and studies of technologies which can incorporate the valuable insights of these action sociologists' work but also have the potential for overcoming their problems.

We illustrate our arguments with reinterpretations of the action theorists' own material; by indicating existing studies which have successfully integrated different levels of analysis; and with examples of our own research for which an exclusive focus on action is inadequate.

We have come from a different background, and have been primarily concerned with working from the macro end 'downwards'. We thus find ourselves contesting the middle ground with these authors: between the broad properties and dynamics of a social system, with which structuralist approaches are more comfortable - classes, sectors, modes of production, economic cycles, or whatever - and the detail of action analysis. This is where the social analysis of technology is most in need of a firm theoretical underpinning, in terms of the politics of organisations involved in developing and implementing technologies.

It is the chosen ground of these writers' attempts to elevate action categories and concepts. Equally it is the level at which radical analyses of the state, and reformulations of, for example, organisation theory, are beginning to be applied usefully.

COMMON GROUND

Let us state at the outset that we have found much of value in the approach of these action sociologists of technology (2), in their case studies and their emphases, and much that we would agree with and support. They encourage exploration of the complexity of the set of events surrounding a particular development. This is a welcome antidote to the reductionism of many frameworks, and allows for multiple influences. With a stress on an unfolding and unpredictable process, the approach allows for changes in the character and objectives of actions resulting from interactions. It acknowledges the problematic nature of technological advance, the possibility of redirection at any point, the plasticity of outcomes. It thus not only contributes to a critique of technological determinism, but also effectively counters instrumental notions of technologies as tools, chosen and applied in pursuit of predefined objectives, with unproblematic results - in other words, as some simple expression of the operation of broader social and economic forces. The action approach shows the intimate interweaving of technical and social elements. It stresses in particular the social construction of the technical knowledge embodied in artefacts and about their functioning. It allows us to push back the boundary between what is accepted as technically determined and what can be seen as socially constructed constraints on choice. The approach emphasises the importance of studying the specific locales of technological development and decision-making. The case studies these writers have chosen, and their presentation, have been rewarding and rich in insights.

CRITICISMS

We find a number of problems, however, in their theoretical expositions, in their claims for their project, and in their actual analyses. Some of them we see as arising from the transfer of inappropriate categories and findings from the study of science (3). Some we see as more general shortcomings of micro-sociological approaches, in their various attempts to negate or reformulate 'macro-sociology'. There are significant differences of emphasis and approach among the writers we are considering, and their location in the more general debates on the micro/macro divide. There are also ambiguities and inconsistencies within particular writers' work, which make them difficult to

pin down. We shall endeavour to make appropriate distinctions, but we feel justified in treating them together here, first because of their shared basis and the contrast to our own approach, and second because of their own collaboration.

PROBLEMS IN EXTRAPOLATING FROM SCIENCE TO TECHNOLOGY

The micro-sociologists have assumed or asserted that science and technology as activities and products can be treated similarly (4). This starting point leads to a number of difficulties and pitfalls. Elsewhere, one of us has discussed the problems of an early formulation by Pinch and Bijker which posited a new paradigm for the sociology of technology applying concepts from the sociology of scientific knowledge (5). In particular the notions of 'closure' of scientific debates and 'success/failure' of scientific theories are inappropriate when imported to the analysis of technology. For example closure in science brings connotations of consensus within a scientific community. In contrast, a technological solution may be imposed without a consensus amongst the various groups involved.

Were the writers restricting their attentions to processes internal to technological communities, we could accept similarities at least in form between the practices and activities of scientific and technical personnel (an R & D laboratory may be very similar in appearance to a science laboratory), the forms of knowledge deployed and generated, and the processes by which outcomes were negotiated. Detailed examination and comparisons could be fruitful, provided the parallels were not pushed too far. However the micro-sociologists have become mesmerised by apparent similarities across the range of scientific and technological activities. They emphasise the links between the two areas and the blurring of the boundaries between them. For some authors, the distinction breaks down entirely. The authors have thereby overlooked some important distinctions.

In criticising their position, we are not saying that there is a clear dichotomy between science and technology - such a view involves an idealised characterisation of these activities that is largely unrepresentative. However there is a spectrum of scientific and technological activity across a range of

conditions. And there are large and significant differences between different points along this spectrum in the conditions under which scientific/technical communities operate and in their relationships and interactions with outside groups and structures. These are expressed in differences in the ideologies and rationalities underlying scientific and technological practice. For example, there are differences in problem definition and objectives. Finally, we point to differences in the forms of social influence: in the directness and manner in which practice relates to wider social interests.

We can summarise some of the major differences under three inter-related headings: the structure and boundaries of communities, their internal and external orientations, the relationship between the production of knowledge and its material realisation.

1) The production of scientific knowledge may be characterised by (and arguably requires) the maintenance of a relatively high degree of isolation of the scientific community, its institutional separation from other communities and its internal social integration and theoretical cohesiveness (6). At the other end of the spectrum, technological practitioners are extremely heterogeneous and may be dispersed and divided from each other. A 'technological community' may thus be amorphous and hybrid (7).

2) Though other concerns and interests doubtless influence scientists, the primary orientation of academic science is internal, around the production and reproduction of knowledge, towards goals of theoretical advance. As we move across the spectrum we find that technological knowledge becomes more concerned with the direct pursuit of ends set externally; in particular it is strongly and explicitly orientated around economic and political goals (8).

3) In the above discussions we have addressed science and technology as if they were concerned solely with the production of knowledge. In technology such an identification, is inadequate and misleading. The micro-sociologists have often made explicit their reduction of 'technology' to 'technological knowledge' (9), in an effort to direct attention to this particular element to the exclusion of its material manifestation, context and effects (10).

In contrast we would argue that technology can only be understood if one looks at the conditions of its realisation as well as those for its inception. Since technology is orientated towards ends, its significance must be assessed in the light of its consequences. This is why we argue it is necessary to study the implementation and use of technology as well as its design and development. Implementation clearly involves political and economic processes that cannot be reduced to the production/dissemination of knowledge (11). When implementation and use are taken into account, the range of social groups involved and affected by technological change expands enormously, going far beyond anything recognisable as a technological community. This creates huge problems for the application of a framework from the sociology of scientific knowledge that starts from the identification of a definite network of actors. The 'actor-network(s)' appear to grow explosively once outside the R & D laboratory and become hard to handle analytically (12). The micro-sociologists have made different, if ultimately unsatisfactory, attempts to resolve this problem (see below).

We accept limited parallels between processes internal to scientific and technological communities. Studies of technological communities and of the knowledge component of technology are being undertaken (and not solely by micro-sociologists) and are extremely welcome. However there are (at least) three pitfalls in applying micro-sociological approaches from the sociology of scientific knowledge to technological change.

First is the temptation, to which some micro-sociologists have succumbed, of being extremely selective - choosing technologies for study in which the institutional structure and practices exhibit the greatest similarly to science. This is reflected in their emphasis on emerging rather than established technologies, on development at the expense of implementation, on radical innovation rather than incremental innovation. By focusing on what is only a small part of technological activity, they run the risk of producing a distorted picture of technological advance.

Second, such studies may become absorbed in the internal intricacies of development and lose sight of the objective of demonstrating connections to wider interests - opening up the black box and getting inside it, so to speak, only

to close the lid behind them.

Last but not least is the danger of projecting the relationships found in the R & D laboratory more widely than appropriate, onto the broader structure of society. This the micro-sociologists have done with a vengeance.

Paradoxically these writers have chosen to apply their approach with a broader scope that goes well beyond what could be identified as a community of technologists. The studies we are examining mostly concern wider interactions, among groups responsible for implementing as well as developing technologies: Hughes' 'system-builders', Law's heterogeneous engineers, Latour's Machiavellian princes. It is with these attempts to take on wider social processes that we shall engage here.

MOVING BEYOND TECHNOLOGICAL COMMUNITIES

The contributions vary in their attitude to the existence of macro-social structures, and to the validity of analyses of them (13). Some appear to acknowledge the importance of wider interests but have difficulties trying to graft them on to individualist accounts (14). Others espouse what Law has called 'generalised agnosticism' (15) - rejecting structural analyses and their findings ostensibly in order to maintain an open mind about what empirical studies may show about social systems. Macro level analyses to date - as the writers perceive them - are deemed either dubious or irrelevant. Either way, they insistently refuse to use macro-level concepts and categories, and thereby apparently feel justified in ignoring large bodies of theoretical work and substantive findings (16).

From this grand refusal, varying claims are made about the ability of their approaches to reconstruct the macro from the micro, or in some cases rather to dissolve the distinction: analyses developed for micro phenomena are deemed equally applicable to macro 'actors'. Law argues that the 'distinction between macro- and micro-sociology' simply reflects 'differences in scale' (17). Crucially these accounts suggest mechanisms by which technologies become accepted on a large scale and whereby local micro outcomes gain macro significance. Though each may favour their own particular terminology, the mechanisms

seem broadly similar. Thus Latour (1983) sees the creation and generalisation of a technology and its move from the laboratory to society as a product of 'the success of a group of actors in convincing others to take up their project'. For Pinch and Bijker (1984), it reflects that ability of a social group to 'close' a technological controversy. Callon and Law (1982) see 'actors' enrolled into 'networks' by 'translating' the roles and strategies of others to make themselves indispensable (18).

The conceptual starting point of the paradigm is the actions of individuals and the interactions between them which form a sort of immediate context. The focus is on observable behaviour. Their unwillingness to acknowledge pre-existing structures and their effects - or their difficulty in conceptualising such - leads them to treat actors as if they come to the interactions studied somehow free from their past histories, free from preconceived objectives, free from constraints other than those to be imposed by other groups involved. Actors, motives and objectives are constituted in interaction from a fresh start. Only those actors readily observable as involved in the interaction are included in the analysis. The identity of 'relevant groups' is unproblematic (19).

The approach cannot deal with the prior structuring of actors and arenas: to include certain actors and exclude others, to allow certain issues and technical possibilities to be raised and not others, to allow the articulation of certain interests in explicit objectives and suppress others. It is paradoxical that while Callon, for example, stresses the need to follow a sequence of events to explain any outcome (20), the writers are not prepared to take the analysis back before an arbitrary starting point to consider what forces brought the groups into interaction in the first place.

For the time being we will leave aside the question of whether it is in principle possible to derive large-scale processes from micro-level actions and interactions. The writers claim in their case-studies to be constructing the micro from the macro, or to be eliminating the need to make such a distinction. However the practical impossibility of such a reconstruction from the inside out, without some preconception of wider structures, forces them to fall back on unacknowledged assumptions about the character of the collective actors involved. Their agnosticism towards social structures is actually abandoned for

an implicit model on which they rely by default. In the absence of an acknowledged framework to structure the factors which they find have influenced an outcome, their work remains largely descriptive. Where they have attempted to go beyond the empirical circumstances of their particular cases, they have made some unjustifiable generalisations from quite specific phenomena. See for example our critique of Callons's otherwise very interesting study of the electric car.

Our objections have a familiar ring! We bring to bear many of the points of well-worn critiques of pluralist political models, of behaviourist approaches (the exclusive focus on observable conflict) and related concepts of power and interests, the 'psychologism' of unexplained motivations, and empiricist methods. Though 'methodological situationalism', as Knorr-Cetina terms it (21), may draw the limits of inquiry slightly wider than individualism, we do not believe it to be exempt from the same criticisms and requirements. The very conception of macro-actors as 'actors' leads to individualistic assumptions about their effective behaviour: for example, that they have a coherent identity rather than an internal structure with divisions and contradictions, that they have an objective which can be expressed like an individual preference rather than being constructed in internal processes. We do not accept that institutions such as those of the state, or indeed the state as a whole, can be treated in the same way as an individual actor.

Here their approach leads, paradoxically, to a view of technological development as much more malleable than is the case. It overstates the power and autonomy of local actors, which are seen as capable of imposing their will. There is no explanation of the external conditions under which the attempt will fail, except through failure to build alliances with 'powerful actors' (or to unite with them and become big or powerful actors) (22). Perversely this 'over-politicised' view of technology - an overblown significance accorded to scientists and technologists as shapers of society - (re)creates a form of technological determinism (23).

The view of technology has a certain rather romantic appeal. Its plausibility is, we believe, enhanced by the selectivity in its proponents' choice of technologies for study. They tend to focus on the early stages of development of radical new

products. Here the utility of the technology may be uncertain, and may indeed need to be negotiated with users before a market is established. The implications of the innovation for existing interests may be unknown, and new interests may be constructed around it.

But this focus ignores the bulk of technological change, which consists of: incremental innovations along well-defined trajectories; the advance of entrenched programmes and systems; and industrial process technologies. In these areas, developments proceed in a context of already strongly- articulated economic and social interests. Here the opportunities for re- negotiation of technologies (or social relations between institutions) are highly constrained. The operation of these constraints can best be explained by reference to broader socio-economic structures and practices, to interests and ideologies. For example in capitalist societies technological change in the workplace takes place in a context of national and international markets, a legal structure and an ideological system which locates and organises the roles of workers, trade unions, employers, and technologists. Micro-sociologists, by reducing these structures to interactions between observable institutions (actors) either promise explanations that would be mind-bogglingly unwieldy (and as such unworkable), or are forced to simplify these interactions so far that they amount to the operation of a rather crude conspiracy.

THE NEED FOR BROADER ANALYSIS

In a recent paper Callon and Law develop the micro-sociological model to show how, in three cases, individual scientists were able to transform (translate) the context - the terrain in which they were operating. In emphasising the negotiability of macro-structures, they 'reject macro- determinism and with this any form of large-scale social (or technological) determinism' (24).

We sympathise with their rejection of some structuralist approaches which cannot accommodate action. For example: structural functionalist frameworks, treating human actions as functionally adjusted practices contributing to the operation of stable sub-systems, or Althusser's Marxist structuralism explicitly excluding human agency except insofar as agents are bearers of structurally determined social relations. But to equate all appraoches which stress the

importance of broader structures, or to parody them, and to discard them altogether, is both unnecessary and unhelpful. Our key difference with the action sociologists of technology is that we believe such a wider analysis to be possible and indeed essential.

1) There are levels of explanation for which a broader analysis is required. We contend that no conceivable number of micro analyses would allow us to explain the general characteristics of a society's technological ensemble, the nature and rate of change in different areas, and the features of entrenched technological systems. We see no reason for rejecting analyses which use macro-level concepts of social forces, dynamics, and so on, when they are seen as summary expressions of the objective workings of social systems, and are subjected to appropriate forms of test. For example we think there is much of value in bodies of literature such as that on the economics of technical change - a field which these writers largely ignore. While we might wish to criticise or reinterpret its findings we would argue it is an essential contribution to the overall endeavour. Though dealing with different categories, such analyses can be quite consistent with analysis of detailed interaction.

2) As we attempt to show in our criticisms and in the examples in this paper, analyses of broader structures are essential to understanding the context within which detailed interactions take place: in short, interactions cannot be explained in their own terms. An acontextual account is underdetermined analytically. It leaves unexplained so many features: why the particular groups identified should be involved; their starting points; the different conditions affecting them; the ramifications of their actions, and so on. Moreover, these accounts obscure the possibility of opening up alternative courses of political action through more fundamental changes in underlying conditions.

EXPLAINING AN ABSENCE: CHP/DH

We can illustrate these points with reference to one of our own studies - the absence in Britain of an energy technology well-established in other countries: combined heat and power (CHP) for district heating (DH) (25). Here we simply raise a set of questions about the selection of technologies which we would argue cannot be addressed in an exclusively action framework.

Examination of observable activity around CHP/DH does yield interesting material. Activity is concentrated in several distinct periods since the turn of the century, when the basic idea was worked out. There is evidence of extensive advocacy and debate, and numerous assessments and proposals for schemes - virtually all of which were abandoned or went ahead only in vestigial form. Analysis at this level may be able to explain in a limited sense why particular proposals failed; usually the immediate reason was that promoting local authorities accepted that the economics was precarious at best and their resources too limited.

This, however, leaves a host of unanswered questions requiring a wider scope of inquiry. Why was the economics so narrowly assessed? By what process did the original socially defined objectives for the technology - in terms of better domestic heating, energy efficiency, employment, regeneration of inner cities, and so on - get reduced to narrow financial considerations? Why were there periodic surges of political support for CHP/DH, so that at times little activity can be traced, whereas in the period of postwar reconstruction and following the energy crisis of the mid-70s it was much more central to energy debates and was assessed in terms of its national potential? How did these national programmes degenerate into a collection of a few scattered separate plans, left largely to the mercy of the existing institutional framework? Why was no central agency set up to pursue the option?

The study was thus designed to include a more general analysis of the British energy sector. It was argued that the reasons why certain options are more or less systematically excluded and only occasionally thwarted by active resistance lie in features of its basic structure and character:

- with production organised in highly centralised and vertically integrated chains;
- with energy forms in competition for certain intermediate and end- users;
- with producers having limited political accountability and coordination;
- with users as consumers of commodities; and
- with a particular entrenched policy paradigm and ideology.

In this case, the exclusion of the CHP/DH option is a product of the substantial change that its introduction would require in economic and organisational conditions (and the onerous political demands that would be involved in achieving these changes). More fundamentally it reflects the challenges that the introduction of CHP/DH would represent to established interests in the sector and more widely. Conversely, the chances of significant development of CHP/DH - and fulfilment of the social objectives with which it is identified - remain poor as long as wider organisational reform of the sector is not tackled.

Overt conflict around CHP/DH - for example between the newly nationalised electricity industry and the responsible government department in the 50s, or between gas companies and local authorities over local legislation for schemes in the late 40s - was very limited. But even if we focus on the behaviour of those organisations centrally involved, it is impossible to understand their position on this option without analysing their wider social location and their mainstream activities. Thus the coal industry was a major opponent of DH in the 40s and 50s, seeing it as a competitor in the domestic heating market. Yet in the 60s it was the main force behind the revival of DH, as a way of at least stemming the loss of the same market to other fuels. The electricity industry's position on CHP cannot simply be derived from its statements or its mandate; rather it is necessary to explore the way its dominant technology and policy paradigm - favouring centralised condensing generation and increasingly nuclear power - became entrenched, and thereby marginalised alternatives. With the major actors in the sector being public bodies - local and central government and the nationalised industries - we have turned, as in later examples, to a general analysis of the state to help in understanding their basic character.

POLITICAL ANALYSIS AND THE STATE: ELECTRIC CARS AND LEAD PAINT

Let us move on to some more examples centrally involving the state. We want to contrast our own analysis with that in Callon's study of the electric vehicle in France (26). Callon's acontextual treatment of an 'actor' demonstrates his lack of a developed theory of the relationship between the state, the economy and civil society. This results in his misjudging the generalisability of his

findings, confusing the necessary with the contingent and cause with effect.

Callon's study deals with a technological project that became diverted and was eventually abandoned for social as well as technical reasons. Though mentioning disagreements within the state and between the numerous social groups involved in the debate, Callon focusses on the direct negotiations between these actors, and consequently underplays the ways in which the massive pre-existing interests of industries and groups whose future was closely linked to the petrol driven car, such as the motor industry and the oil industry, created the terrain on which the subsequent struggle took place - a terrain that ensured that the electric car had only marginal support.

Callon observed that 'the state is powerless' when confronted by diverse technological options, conflicting viewpoints of social groups and uncertainty about demand. He suggests that the state 'rarely has sufficient expertise to transform technical controversies into policy debate; it is undermined by internal divisions that prevent it from showing any coherent political will; it is trapped into deals that lead it to defend the most powerful groups.' (27) With these general claims about the state's weakness, Callon's theorisation of the character of its intervention in technological and economic development comes to an adrupt halt.

We have been concerned to develop a complex theory of the state and its relationship to society that can explain the circumstances and limits of intervention by the capitalist state. One of us has studied regulatory policies for lead paint, in the first quarter of the 20th century, when hundreds of paint workers were dying each year from lead poisoning. The study examines the failure of the British state to implement a policy of Prohibition - banning the use of white lead in decorative paints - and its adoption instead of a weaker regulatory strategy of requiring Precautions that was directed at ensuring that these highly toxic materials were used in a 'safe' manner (28)

Some comparable features were observed to those in Callon's study: in that the state's lack of expertise around complex technological issues, and internal divisions within the state apparatus, were important factors limiting and patterning the state's intervention. However these were not the only factors at

work. It was possible (and necessary) to take the analysis much further and address the influence of economics as well as the legal and administrative tradition, ideology and broader political constraints on the role of the state. The collapse of the state's initiative at Prohibition is seen as contingent, and stands in contrast to the successful development of the state's programme of regulation of other workplace hazards (based on a strategy of Precautions).

Fierce struggles in the mid-nineteenth century had established the principle of state regulation of industrial activities and laid the basis for the further extension of regulation to deal with specific hazards. The traditional 'Precautionary' regulatory strategy became embedded in the legal and administrative regulatory structures; it was seen as legitimate, and was supported by state expertise in process-control technology. Though employers resisted the extension of regulation, political mechanisms existed to develop and implement regulatory policies on an acceptable basis. Regulation thus developed within a set of historically specific economic and technical limits. Formal state regulation typically had the effect of bringing the rest of an industry into line with those employers which - through informal pressures from enforcement agencies, trade unions etc., and through modernisation - had adopted safer technological processes. Under these circumstances, the technical solutions were known and their economic viability was demonstrable. Moreover, the immediate economic interests of the more backward employers in resisting extension of regulation were divided from those of more advanced employers, who would tend to favour regulation as an instrument of monopolisation or at least to ensure 'equality of the conditions of exploitation' (29).

In contrast, the Prohibition strategy was encumbered by the exclusion of the state in contemporary capitalist societies from direct control over economic and technological development. It would have involved the state in new and unfamiliar areas - for example, in redirecting the technology of paint formulation an area in which the state lacked the expertise and the legitimacy to intervene. The existing mechanisms for producing economically and politically acceptable regulatory policies were ill- equipped to develop technically viable and consensual solutions around Prohibition, particularly as it involved the destruction of an economically significant industry (white lead

manufacture). In the event the white lead manufacturers, in alliance with other industrial and social groups, were able to force the state to abandon the Prohibition strategy. In comparison Prohibition prevailed in other European countries where manufacturers of non-lead pigments were relatively larger and more powerful, and were allied to social and industrial groups campaigning for Prohibition.

The study is able to explain the pattern of state regulatory activity and identifies some consistent features and processes that operate across different industries, periods and nations. The outcome in this case is linked to the contradictory and conflicting set of economic and social interests with which the state engaged - divisions which were partly reproduced and fought out within the state - and the ways in which those interests were brought together in conflict and alliance in the political processes of regulation. Technological expertise had an important role in this process in both mapping out particular regulatory options and legitimating consensus around them. Though the state's role might ultimately be judged 'weak' in this particular example, the study highlights the conditions in which more interventionist regulatory policies might - and indeed subsequently have - succeeded.

Thus the state is not always powerless. Callon's formulation that the state is tied to the interests of powerful groups is too simplistic, verging on a crude 'elite' theory. It does not do justice to the complex and contradictory relationship between the state and society which recent Marxist studies have begun to identify. The state is capable of making significant interventions into private economic and technological development. However the state's role is not that of a neutral, powerful actor. The case study highlights some concrete, historically defined limits on the character and extent of state intervention.

Reference to a broader theory of the state in society affords explanations of other very different patterns of state intervention in technological development from that found and unjustifiably assumed as universal by Callon. We can point to the concerted programmes adopted by advanced industrial states for information and communication technology. The technical and commercial uncertainties surrounding these areas are surely no less than those in Callon's case of the electric car. But the structure of economically

powerful industrial interests is much more coherent. Analysis of policy development might well be drawn to focus exclusively on industrial elites and governments. Once again we would argue a need to adopt a broader framework that would for example consider why and to what extent certain sections of society are excluded - for example how in Britain labour is currently marginalised from decisions on such programmes, and how differences arise in policy formation between advanced nations that can in part be related to the organisation and policies of labour and its relation to industry and the state.

LABOUR PROCESS THEORY: MACHINE TOOL CONTROLS

For our last example we turn to a well-developed current of studies: of technology in the workplace and its relation to labour processes. Here is a substantial body of research which at its best fulfils both sets of analytic requirements: it entails a detailed focus on action and an openness towards multiple and complex influences on an outcome. It also demonstrates the need for this level of analysis to be related to a broader social structures and processes. The micro-sociologists have tended to overlook or underplay work in this area. In particular they have ignored Marxist labour process analyses in the application of this aproach to technological change and its elaboration. Where such studies are addressed they have, in some cases, misunderstood the approach and its significance. Thus Pinch and Bijker skim over labour process theory as merely dealing with 'the effect of labour relations on technological development' (30). Latour, in setting up a crude picture of Marxist analyses to knock down, cites the deskilling effects of textile technology as one narrow area in which a picture of the simple class nature of technology is perhaps sustainable (31). The leading paper in this area, paradoxically, shows that the deskilling and potentially feminising potential of this technology was never achieved, because of compromises between capital and skilled labour in the industry (32). The analysis highlights the role of inter- capital competition and of patriarchy - forces that cut across a dogmatic two class model which Latour would have us believe characterises Marxist work.

We can illustrate the power and the complexity of the labour process approach by considering the case of Numerical Control (NC) and Computer Numerical Control (CNC) machine tools (33). The design of NC machine tools has been

seen as orientated not simply towards productivity gains but also towards the political objectives of employers - by transferring responsibility and control over machining techniques from the craft machinist to the programmer. NC programming required expensive computer equipment as well as computing skills, and was allocated to technical workers. Noble examined the development of this technology and the suppression of alternatives, such as record-playback, as evidence of such a managerial control strategy (34). He showed that the form of the technology adopted was related to the predominance of military funding, by the United States Air Force, for initial development and use of NC in large aerospace manufacturers. The latter saw NC as not just offering technical and economic advantages, but also strengthening the industrial relations position of management by reducing their dependence on skilled and often strongly-unionised machinists. Many authors have tended to see the development of manufacturing technology as a simple continuation of this strategy, leading to a technological trajectory based on the displacement of shop floor skills. The machine tool case has even been cited by Pinch and Bijker as justifying their action model of technological development, reflecting the success of one social group in articulating their particular concerns over the design process (35).

However, the subsequent development of machine tool technology has exhibited contradictory tendencies that cannot readily be explained in terms of interactions between these social actors. Rather it reflects the complex interaction of a variety of socio-economic factors operating at different levels. For example, changes in the price and capability of microelectronic technology have been an important influence. The rapidly falling cost of memory and computing power facilitated development of CNC machine tools in which the programming equipment is attached to the machine tool. This made it technically feasible and potentially economically attractive to institute shop floor programming of machine tools (36).

The most immediate consideration for machine tool manufacturers lay in differences in the users of machine tools. A large portion of machine tools are used in small companies which had not been able to use NC because of its high capital costs and the extensive technical resources it required: e.g. a mainframe computer, 'post-processors' and tape preparation equipment, computer

programmes. The development of CNC opened up this massive potential market. Features of many of these new users were favourable to a more flexible division of labour in programming and operating machine tools. As we show below, the lower and looser division of labour typical of many smaller firms, and the operational requirements of small batch production or specialised production, were more compatible with shop floor programming. Facilities for shop floor programming became incorporated in machine tools, and indeed became a standard feature.

This development had unanticipated side-effects, not desired by the groups originally involved in the development of NC. CNC opened up opportunities for craft workers to regain control over programming. It was thus potentially subversive to the division of labour established with NC machines. Whereas craft workers had put up relatively little resistance to technician programming of NC machine tools, responsibility for programming CNC has been fiercely contested between machinists and technicians in many engineering factories in Britain and the USA (37).

The technological trajectory established under NC appears to be diverging under CNC, with a range of organisational solutions on a continuum between centralisation and decentralisation of programming (38). The determinants of this divergence are to be found in the broader context, outside the web of actors immediately involved in the development of NC. In theory it could be explained within an action framework, by rapidly expanding the network of 'relevant groups'. The number of organisations involved would make such an explanation unwieldy. Moreover, the interactions between organisations took place usually at one remove, mediated through broad markets for microelectronics and for machine tools. There is little indication that the implications of these new factors and the change in technological paths were recognised by the actors involved.

The factors affecting choice of work organisation and operational arrangements with CNC have been studied intensively. In particular, Sorge et al. have conducted a large scale survey of CNC use in Britain and Germany (39). While noting the variability in precise arrangements, they identify a set of factors which systematically influence the degree of polarisation of skill and

responsibility adopted. For example a high division of labour on the shop floor between machine operation, setting and programming was associated with large batch size. In larger firms, programming tended to be more bureaucratised: it was allocated to specialised technical staff in programming/planning departments - particularly in firms which had used NC; possessed Computer-Aided Programming equipment; and in which there was an already established divison of labour at shop floor and departmental level. In contrast, operator programming was more common in smaller firms or plants, in which there was less differentiation and formalisation of structures and roles.

These 'sociotechnical' characteristics of a particular CNC application (e.g. product characteristics such as batch size and product complexity, and the level and distribution of workforce skills and training) were an important influence on the organisational arrangements adopted. However they were modified by a range of influences at other levels - including macro-economic factors, the market location and strategy of the firm and national/cultural differences. Organisational choice was shaped by interactions between these levels which offered more or less competing logics. For example, national/cultural differences, historically moulded and embedded in the industrial relations structure, were reflected in greater operator involvement in programming in Germany than Britain, other factors being equal.

The influence of the socio-technical dimension can be illustrated in relation to product characteristics. Programming of geometrically complex products favours the use of Computer-Aided Programming - by technicians. Conversely machining to fine tolerances or with materials that are variable or difficult to cut places a premium on metal cutting skills and greater involvement of craft/manual labour in programming - given the current unpredictability of metal-cutting processes around which machinists may possess considerably more expertise than technician programmers (40).

The strategies of groups outside management may also be significant - including resistance from strongly unionised craft workers and even possible militancy of technician-progammers. However, the ways that different groups within the firm perceive and articulate their interests are shaped by the

industrial relations and other structures that exist for interest representation. For example, the occupational fragmentation of the British trade union structure, with diferent unions organising machinists and technician programmers, favours a sharp demarcation and a clear division of labour and limited mobility between these two groups - in contrast to the industrial unionism in Italy and other European countries (41). Thus the apparent economic and political advantages for employers of technician programming have to be offset against the current operational problems that this may involve.

The current dichotomy in arrangements for use of CNC can thus be seen as a product of a set of complex and contradictory requirements favouring a higher or lower division of labour - of divergent pressures in the selection environment (42) In the longer term, considerable uncertainty remains about the optimal arrangements for more Advanced Manufacturing Technology; the image of the 'workerless factory' is balanced against the experience that an extension of workforce skills may be required for successful implementation (43). These alternative perspectives are reflected in diverging approaches to future technological advance: the former might indicate the need to find technical solutions to minimise operational uncertainties and the consequent requirements for shop-floor expertise (e.g. with Direct Numerical Control where the machine tool is directly linked to the programming/scheduling computer); the latter might suggest the need to combine technological and organisational change (e.g. experimenting with cellular organisation/group work for CNC or Flexible Manufacturing Systems).

The emergence of the latter approach has been seen as prefiguring a general shift away from traditional forms of organisation of the labour process - based on Taylorist principles of work organisation involving centralisation of skill - towards a new (neo-Fordist) system of production reflecting the changing dynamic of competition within capitalist economies (44).

Inquiry and debate in these areas continues. However, as the NC/CNC case shows, we already have a rich set of accounts for the complex processes of development and implementation of this new technology. Analysis has highlighted influences at a range of levels, and the interaction and links

between them: from the groups involved in development and use of the technology, their interests, objectives and perceptions, through the institutional context (firm and industry structure, industrial relations system) to broader 'logics' (national/cultural differences and economic pressures).

The micro-sociologists' incursion into this literature seems to have halted with Noble's work. We suggest that they need to address this body of research and either explain their reasons for rejecting it, or attempt to show how it could be incorporated within their perspective, and how they could provide a more effective explanation. The latter might present the micro-sociologists with some difficulties. For example the various structural influences outlined above can readily account for marked similarities in CNC operating arrangements found between firms that have no direct contact with each other but that are similar in terms of size and product characteristics. How useful is the actor-network concept in explaining these similarities?

THEORETICAL OUTLINES: SOCIAL MODEL

Contrary to the working assumption or theoretical assertion of the action sociologists we hope to have demonstrated that broader analyses are essential. Coherence in a theory of the social shaping of technology must come not through unwarranted generalisation from one specific context, but through a coherent model of the society in which different technologies emerge and are embedded. Thus many of the problems encountered in understanding technology will come from a disparity in the depth to which different domains and levels of society have been analysed.

Moving towards a conclusion, we shall outline some approaches we consider particularly relevant for broader social analysis. It will be clear that in substantive terms we accept a broadly Marxist social model. In the industrialised Western nations, the structure and dynamics of a capitalist mode of production are in some sense basic to the social formation, and hence to the contexts of technology in all domains of social life (45). We take our inspiration from recent theoretical works and concrete analyses which undogmatically take this as a starting point and seek to understand the character of the society, including its technology, in terms of the particular features of that mode of

production and the complex articulation of social interests which have developed in and around it. We are referring here to work that has addressed the complex and often contradictory interests of sections of capital and of labour, different parts of the state, professions, divisions of race and sex and other social movements.

For example, an understanding of technology in manufacturing cannot be obtained from studying just management decision processes or management-labour conflict within a firm - as labour process theory has come to acknowledge. It involves analysis of product markets, competitive environments and other economic pressures, the support and regulatory environment provided by the state, labour markets, and the more general balance of power between capital and labour. The pattern will vary from sector to sector. We can then start to relate technological strategies to historically specific constraints, pressures and opportunities.

In reproduction - in housing, in welfare provision, in education, in the family, etc. - another complex set of interests pertain. These are affected by the patterns of individual and collective consumption, the balance between the private commodity mode and the collective service mode of consumption, the nature of employment in these areas, and the intervention of the local state in them. These need to be analysed at a broad and a detailed level if we are to understand the character of technologies in them.

Across production and consumption, we encounter the pervasive importance of the state in technological development and choice - state funding and direction of R & D; state initiatives in strategic generic technologies; the dominance of military objectives; state ownership of infrastructure and other production facilities; state purchasing and investment; state regulation; state mediation between management and workforce; political and legal battles between developers of major projects and objectors; and so on. We need, as we have argued earlier, an analysis of the state which can not only relate in general terms its scope, organisation and intervention to the development of the economy, but which can also acknowledge the multiplicity of influences operating through it - differences in the mode of politics in different domains and the specific limits to its interventions.

We do not imply by this that an explanation should be deduced from the state or the mode of production. We simply argue for the need for a theoretical approach that is capable of addressing this broader context. Like the micro-sociologists we would emphasise the importance of conflicts and alliances between groups, but would maintain that these alliances are structured beyond the level of direct interaction. This in part could arise from collective interests, arising from the shared location of groups within a social structure - though it should by now be clear that we reject crude approaches which see collective interests as simple, uniform and fixed. The micro-sociologists have made an important contribution to the body of research which examines how interests and alliances are directly negotiated. We would suggest to them that the concept of hegemony in Marxist political writings, drawing particularly on Gramsci, can help to explain how interests are combined and (re)articulated, and alliances cemented at a broader social level. Indeed Gramsci's emphasis on the key role of intellectuals in the production and maintenance of consent provides a useful opening for broader analyses of technologists and system builders (46).

THEORETICAL OUTLINES: RELATING LEVELS OF ANALYSIS

The second theme of our theoretical argument is that these sorts of broader analysis can be both consistent with a detailed account of action and complementary to it. Here we point to works we think are useful and resolve, at least at an abstract level, both the problems which cause action theorists to reject structural approaches and those which they themselves get into. We see potential in such frameworks as Giddens' structuration; Jessop's conception of the complex chains of determination producing specific conjunctures; Clegg's recursive model of structure, mediation and action; and reformulations of more limited fields such as those by Benson and Reed of organisation and interorganisation theories (47). We do not wish to understate their differences, but contend that broadly similar guidelines for studying a particular topic, and similar notions of key concepts like power and interests, emerge from each (48).

Starting from the inside out, so to speak, our model of action must acknowledge not only the purposive action dealt with in micro-sociological

accounts, but also the bulk of action in the form of practices - constrained, largely unquestioned, drawing on tacit practical knowledge, orientated towards some underlying set of objectives - which as integrated assemblages constitute and reconstitute social systems (49). Action, in the limited form treated by the micro-sociologists, appears only as a manifestation of contradictions within and between institutions; action is taken to challenge existing procedures or to defend them in the face of challenge.

From the outside in, however, the institutional context within which activity takes place provides the incentive for action to innovate or to maintain existing arrangements. Analysis of context allows explanation of the identity and initial composition of the actors involved and - as we stress throughout our examples - those not involved, and their interest in particular potential outcomes; and the differential sets of constraints under which they act and of resources on which they can draw in interaction - conceived in a broad sense to include political and ideological elements as well as economic. It seems reasonable and valid, as we have indicated, to take the effects of social systems as impersonal structures confronting or influencing actors as constraints and opportunities. Context further determines the ramifications following any particular action. Giddens' model of action in particular allows for and stresses the unacknowledged conditions surrounding any actor and the unintended consequences of its actions. Outcomes, then, are not, as micro-sociologists' theoretical framework would imply, infinitely plastic; recognising the specific constraints and possibilities for change at different levels is essential both to an adequate analysis and to political interventions in the process.

We share with these writers, however, the argument that there is no simple correspondence between interests and objectives, power and outcomes. Processes therefore need to be reconstructed and argued. There can be no question of a predictable result from somehow reading off and adding up capabilities and constraints from a context. First, the determinants of a particular area of activity are many, complex and interrelated, and cannot be reduced to any single principle. Second, the prior theorising of many organisations is still poorly developed from the viewpoint we would take.

We believe then, that an interactive model of the relation between context and

action is the key to overcoming the separation of micro and macro approaches to understanding technology as a social product, with different but consistent forms of analysis appropriate to each, rather than an application of the same action concepts regardless of level. Methodologically, too, our approach should be interactive, in this sense: we suggest a set of conditions and mechanisms which should explain particular activities and their outcome; we use our empirical study to reflect on the adequacy of that set. Our depiction of any level remains provisional.

SUMMARY

We conclude with a brief resume of our position which points to opportunities for synthesis and further research.

We have examined a range of recent writings by a group of 'micro- sociologists' who appear to be collaborating in an attempt to apply frameworks from the sociology of scientific knowledge to the social analysis of technology. Their investigations have been stimulating and empirically rich. We welcome their contribution, but have sought to point out limitations in their approach. In particular, their exclusive focus on 'micro-level' action and interaction between individuals and groups neglects the role of broader structural influences. Their use of inappropriate frameworks impedes their analyses and leads to problems in their case-studies - for example over-generalisation from specific outcomes. They underplay the extent to which actors are constituted, and their interactions are shaped by their specific historical and structural context. We argue that a rejection of all those approaches which address structural influences as determinist is mistaken. This may explain why the group seem to downplay or ignore a large and valuable body of existing socio-economic research on technology.

The final section of our paper has outlined how analysis of action and structure can fruitfully be combined - in the study of technology and more generally. Preceeding sections sought to demonstrate the possibility and the need for such an approach by reference to our own studies of technology policy (in relation to the energy sector and to state regulation of hazards) and to the body of research of technological change in the workplace. We contrasted this with the micro-

sociologists' treatment of similar areas (Callon's study of the electric car and the inadequate handling by this group of the labour process). We are keen to continue our programme of analysis, to demonstrate its utility and develop it, through further empirical studies and reinterpretation of existing material.

Despite our very different starting points we find much common ground with the micro-sociologists: in a concern with detailed processes and a critique of technological determinism and crude structural analyses. The group of micro-sociologists are not monolithic, and their perspectives are still developing. We shall be interested to see whether and how far a synthesis incorporating the critique here is possible. Social-economic research on technology is a large and growing field. Critical research approaches need to be expanded and elaborated (on both academic and policy grounds) in the face of the burgeoning of 'atheoretical' empiricist research. There are obvious temptations, particularly for new arrivals in the field, to stake out paradigmatic claims to the social analysis of technology and reject existing research and criticism. Some of the micro-sociologists appear to be succumbing. We would regret such a development which could further fragment analysis in this field, delaying its development and dissipating its impact.

NOTES

1. M Callon, 'The State and Technical Innovation: A Case Study of the Electric Vehicle in France', Research Policy 9, 1980, pp 358-76; B Latour, 'How to Write "The Prince" for Machines as Well as for Machinations', paper to conference Technology and Social Change, Edinburgh, June 1986; J Law (1986a), 'The Anatomy of a Sociotechnical Struggle: the Design of the TSR2', paper to conference Technology and Social Change, Edinburgh, June 1986: T Pinch, 'Understanding Technology: Some Possible Implications of Work in the Sociology of Science', paper to conference Technology and Social Change, Edinburgh, June 1986; T Pinch and W Bijker, 'The Social Construction of Facts and Artefacts: How the Sociology of Science and the Sociology of Technology Might Benefit Each Other', Social Studies of Science 14, 1984, pp 399-41; W Bijker, 'Social Groups and the Technological Styles: Towards an Explanation of the Developmental Process of Bakelite', in C&C/EASST/4S, George Sarton Centennial (Communication & Cognition, 1984), pp 329-32. For further indications of their approach, see: M Callon and B Latour, "Unscrewing the Big Leviathan: How Actors Macro-Structure Reality and How Sociologists Help Them Do It', in K Knorr-Cetina and A Cicourel (eds.) Advances in Social Theory and Methodology: Towards an Integration of Micro- and Macro-Sociologies (RKP, 1981), pp 277-303; M Callon and J Law, 'On Interests and their Transformation: Enrolment and Counter-Enrolment', Social Studies of Science 12, 1982, pp 615-25; J Law (1986b), 'On Power and its Tactics: a View from the Sociology of Science', Sociological Review 34, 1986, pp 1-38.

2. We have a problem here with a collective term for these authors. They use the term 'micro-sociologists', though this label is perhaps unfair in that they wish to dissolve the macro/micro distinction in some way. It would, however, reflect our contention that their methods and concepts are those of individualist micro-sociology. For a good general review of micro-sociological approaches, their origins and claims, see K Knorr-Cetina, 'Introduction', in Knorr-Cetina and Cicourel (eds.), op.cit, pp 1-47.

3. In addition we have certain misgivings about some elements of the relativist project in the sociology of science, which we shall not pursue here.

4. See for example: B Latour 'Give me a Laboratory and I Will Raise the World' in K D Knorr-Cetina and M Mulkay (eds.), Science Observed, pp 141-170, (Sage, 1983); Pinch and Bijker, op.cit.

5. S Russell 'The Social Construction of Artefacts: a Response to Pinch and Bijker', Social Studies of Science 16, 1986, (2), pp 331-46.

6. H Radder, 'Experiment, Technology and the Intrinsic Connection Between Knowledge and Power', Social Studies of Science 16, 1986, pp 663-83.

7. P Weingart, 'The Structure and Technological Change: Reflections on a Sociological Analysis of Technology', in R Laudan (ed.), The Nature of Technological Knowledge: Are Models of Scientifc Change Relevant? (Reidel, 1984), pp 115-42.

8. In particular, as Weingart (op.cit., p.118) points out, "the market is the clearing mechanism for the selection (acceptance or rejection) of technologies..."Though it "does not determine directly the production of new ones... cost considerations do enter the decision-making process of construction as a general parameter and determine the design process in a general way."Economic criteria interact with political criteria, including state regulation and promotion of technologies, and general criteria of social acceptability of technologies.

9. Or as 'cultures' as well as knowledge systems; e.g. T Pinch and W Bijker, 'Science, Relativism and the New Sociology of Technology', Social Studies of Science, 16, 1986, pp 347 - 360.

10. For an approach which takes this concentration on technology as knowledge to an extreme, see R Laudan, 'Introduction', in Laudan (ed.), op.cit., pp 1-26. See also E Layton, 'Technology as Knowledge', Technology and Culture 15, 1974, pp 31-41.

11. This is one reason why we insist on a definition of technology as operating across a range of dimensions and levels of social activity and resist analysis which reduces it to a single dimension - whether of knowledge or of economics.

12. Pinch and Bijker (1984, op.cit., pp 430-1) acknowledge that their methodology, which starts with the identification of 'relevant social groups', though 'fruitful' in the study of science, 'presents problems for the micro-study approach' to technology. They state their belief that the problems can be resolved but do not indicate how.

13. The tendency in much micro-sociology to conflate objective conditions with subjective constructs of them - an implicit denial of the existence of context other than through subjective constructs - is seen in some of this work; e.g. Callon and Law, 1982, op.cit., p.622. See Callon and Latour, 1981, op.cit., pp 289-92 for what seems a deliberate attempt to confuse the issue.

14. e.g. Pinch and Bijker, 1984, op.cit.; see Russell, 1986, op.cit. pp.334-5.

15. Law, 1986a, op.cit., p 4.

16. It is not always clear what forms of 'macro-sociology' these authors are reacting against. In general, Knorr-Cetina (op.cit. p 2) suggests 'the upsurge of recent micro-sociological orientations must be seen against the contrast of the normative model of order, and not against the contrast of a conflict model informed by Marx.'

17. Law (1986a, op.cit., p.1 and p.5) argues that the differences in scale 'should be seen as the outcome of differentially effective attempts by scientists to impose versions of scientific and social reality.' In this he uses a very similar formulation to Latour (1983) who argues that the separation between 'inside and outside the laboratory' reflects 'only differences in scale'.

18. Latour, 1983, op.cit., Pinch and Bijker, 1984, op.cit.; Callon and Law, 1982, op.cit.. For Callon and Law 'the [translation] approach is indifferently available to the great and small, because it is precisely about how it is the small become big (or vice versa), and why it is that some succeed while others fail.' (1982, op.cit, p.612).

19. e.g. Pinch and Bijker, 1984, op.cit., p 414. See the criticisms of this view in Russell, 1986, op.cit., p 335.

20. Callon, op.cit., p 359.

21. Knorr-Cetina, op.cit.

22. See note 16. The only inequality is inability to 'manipulate and transform' subjective interests and allegiances. Though there might be a 'backcloth' of prior interests, Callon and Law would 'aim ... to avoid attributing any special status to the backcloth.' (op.cit., p 622)

23. Thus Latour argues (1986, op.cit. p13) that 'science and technology are politics pursued by other means.' Latour (1983, op.cit.) in 'Give Me a Laboratory and I Will Raise the World', imputes a privileged position for scientists and technologists (the laboratory) in generating new visions of society and new sets of social relationships.

24. M Callon and J Law, 'Economic Markets and Scientific Innovation: Notes on the Construction and Socio-technical Networks', mimeo, March 1987, p 55.

25. S Russell, The Political Shaping of Energy Technology: Combined Heat and Power in Britain (Ph.D. thesis, Aston University, 1986).

26. Callon, 1980, op.cit.

27. ibid., p 357, summary.

28. R Williams, The Formation and Impact of Hazard Control Policy: A Study of the Regulation of White Lead Paint in Britain (Ph.D. thesis, Aston University, 1984)

29. K Marx Capital: Volume I (Penguin, 1976), p 621.

30. Pinch and Bijker, 1984, .op.cit., p 406.

31. Latour, 1986, op.cit. pp 8-9.

32. W H Lazonic, 'Industrial Relations and Technical Change: the Case of the Self-Acting Mule,' Cambridge Journal of Economics, 3, 1979, pp 231-262.

33. H Braverman, Labor and Monopoly Capital (Monthly Review, 1974)

34. D Noble, 'Social Choice in Machine Tool Design: the Case of Automatically Controlled Machine Tools', in A Zimbalist (ed.), Case Studies in the Labour Process (Monthly Review, 1979).

35. Pinch and Bijker, 1984, op.cit.

36. Noble, 1979 op.cit.

37. Noble, op.cit.; B Wilkinson, The Shop Floor Politics of New Technology, (Heinemann, 1983)

38. R Williams, 'Democratising Systems Development: Technological and Organisational Constraints and Opportunities', in G Bjerknes et al. (eds.), Computers and Democracy (Avebury 1987).

39. A Sorge et al., Microelectronics and Manpower in Manufacturing: Applications of CNC in Great Britain and West Germany (Gower, 1983).

40. R Williams and F Steward, The Role of the Parties Concerned in the Introduction of New Technology - Case Studies on the Implementation of Collective Agreements on New Technology in Britain (European Foundation for the Improvement of Living and Working Conditions, 1984)

41 Ibid; B Jones, 'Technical Organisation and Political Constraints on System Redesign for Machinist Programming of NC Machine Tools' in U Briefs et al. (eds.), System Design for with and by the Users North-Holland, 1983).

42. R Williams, 1987, op. cit.

43. P Senker, Towards the Automatic Factory? (IFS, 1986).

44. P Blackburn et al. Technology, Economic Growth and the Labour Process (Macmillan, 1985).

45. This is not, as some individualist writers have interpreted it, a reduction of the fundamental dynamic of capitalist societies to a psychologistic attribution of a 'profit motive'.

46. A Gramsci, Selections from Prison Notebooks (translated and edited by G N Smith and Q Hoare) (Lawrence and Wishart,1981), R Simon An Introduction to Gramsci's Political Thought (Lawrence and Wishart, 1984).

47. J Benson, 'Organisations: a Dialectical View', Admin Sci Qly 22, 1977, pp 1-21; J Benson, 'A Framework for Policy Analysis', in D Rogers and D Whetten (eds.), Interorganisational Coordination (Iowa State UP, 1983); S Clegg, The Theory of Power and Organisations (RKP, 1979); A Giddens, Central Problems in Social Theory (Macmillan, 1979); B Jessop, The Capitalist State: Marxist Theories and Methods (Martin Robertson, 1982); M Reed, Redirections in Organisational Analysis (Tavistock, 1985).

48. The notion of interests developed in these contributions, could, we believe, help clarify the unresolved debate on the concept in Social Studies of Science; see Callon and Law, 1982, op.cit.; D MacKenzie, 'Interests, Positivism and History', Social Studies of Science 11, 1981, pp 498-504; S Woolgar, Interests and Explication in the Social Study of Science', Social Studies of Science 11, 1981, pp 365-94.

49. Here is the significance of notions of technological paradigms and the technological trajectories they produce: the particular direction of change is maintained without repeated conscious decision-making but by a set of intellectual practices embodying specific assumptions.) (G Dosi, 'Technological Paradigms and Technological Trajectories', Research Policy 11, 1982, pp 147-62)

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The Programme on Information and Communication Technologies (PICT) is a major initative of the Economic and Social Research Council, which aims to explore social science perspectives on the rapidly evolving Information and Communication Technologies (ICTs) and inform policy debate in the field. The research is conducted by a network of six centres - Brunel University (CRICT); Polytechnic of Central London (CCIS); The University of Edinburgh (RCSS); UMIST (CROMTEC); University of Newcastle (CURDS); and University of Sussex (SPRU) - and coordinated from the University of Oxford.

Edinburgh PICT research is based at the Research Centre for Social Sciences and draws on expertise in the Departments of Business Studies, Economics and Sociology, as well as the Science Studies Unit. The group starts from the assumption that the development and implementation of new technologies cannot be wholly explained by technical considerations, but that complex social, political and economic factors are involved. The research effort therefore focuses on the 'social shaping' of ICTs , at the level of detailed technical design. It aims to elucidate the considerable scope which exists - for both producers and users of technology - to influence the direction and consequence of technological change. Much of the research involves building strong links with the policy community, in industry and in government.

Edinburgh PICT is part of a strong and growing base of socio-economic research on technology at the University, and runs a Doctoral Programme of Social and Economic Research on Technology within the Faculty of Social Sciences. Both teaching and research activities benefit from close links with departments in the School of Information Technology. In addition, members of the Edinburgh group collaborate with researchers in neighbouring Higher Education Institutions, and with other centres in the PICT national network.