WHERE DOES TECHNOLOGICAL CHANGE COME FROM?

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Usually, there have been a polarisation of CTS constructivism studies versus determinist studies, which is not completely real In this sense, the history of Personal Computer shows a special interaction between Sciencie, Technology and Society. It is possible to reach a better analyisis of this history by combining certain approaches of social constructivism with a degree of technological determinism.

Tradicionalmente se ha demarcado un enfrentaminto, dentro de los estudios CTS entre los enfoques deterministas y los enfoques constructivistas, que no obedece realmente a la verdad. En este sentido, la historia del ordenador personal muestra una especial interacción entre ciencia tecnología y sociedad. Es posible alcanzar un mejor análisis de esta historia combinando ciertos enfoques constructivistas con un grado de determinismo tecnológico.

CTS ikerketetan betidanik aurkakotasun bat nabarmendu da ikusmolde deterministen eta konstruktibisten artean, eta horrek ez du zerikusirik egiarekin. Horrenbestez, ordenadore pertsonalaren historiak zientzia-teknologiaren eta gizartearen arteko elkarreragin berezia erakusten du. Historia horren analisi hobea lor daiteke ikuspegi konstruktibista batzuk hein bateko determinismo teknologikoarekin konbinatuz.

WHERE DOES TECHNOLOGICAL CHANGE COME FROM?
Science, Technology or Society?

The question raised in the title of this talk is one of the central theoretical questions of Science, Technology and Society studies. The degree to which technical change can be seen as autonomous from the general process of social change has formed the basis of many of the differences between various schools of thought in STS. It is the purpose of this paper to delineate the main positions in this debate, to show that the polarisation that has existed is to a certain degree artificial and to argue that a version of "social constructivism" which allows a degree of "technological determinism" can give rise, in the area of information technology at least, to a more articulated understanding of the mechanisms that govern the science, technology and society relationship. In the time available, it would be impossible not to oversimplify the general lines of the debate and therefore run the risk of caricaturing to some extent the positions of the various protagonists. In order to try and concretise somewhat what can be a rather abstract debate, I have chosen to illustrate the concepts by using examples from the recent history of Information Technology, partly because I assume most of you will have some knowledge of it, but also because it has been the subject of my own research.

WHERE DID THE PERSONAL COMPUTER COME FROM?

I would like to start setting down the general lines of the debate by posing the general question of the title in a more specific form: "Where did the Personal Computer Come from?" A common way of answering this question runs as follows: The Personal Computer -is the product of advances in the Physics of Semiconductors which led first to the invention of the transistor, then to the integrated circuit which, through the various stages in miniaturisation, made the microprocessor possible and this, in turn, led to the personal computer[1]. In answering the question in this form we are implicitly using what has become known as "the linear model of innovation", that considers technological change

1. Most popular histories of the computer adopt, implicitly at least, this view. See for instance, S. Augarten *Bit by Bit,* Blackwell, 1989.

as result of scientific advances. When this point of view of view is adopted, it is common to go on to talk about the *impact* of science and technology on society. It is, for instance, the position that underlies talk of "the personal computer revolution". It sees technological change arising out of previous scientific and technological developments and then having an impact on society. In this model technological innovation is largely independent of the social context, although it can itself provoke social change. Therefore critics characterize the position as *technologically deterministic.*

If we now return to examine more closely the answer we have given to the question "Where did the Personal Computer Come from?", which appears plausible enough, it is not difficult to demonstrate its limitations. This can easily be done by asking any number of relevant subsidiary questions which clearly are not amenable to the same kind of treatment. For instance "Why has the integrated circuit given rise to the microprocessor?" or "Why has the microprocessor given rise to the PC?". After all, microprocessors can equally be used in mainframe or mini-computers, they needn't have led to the PC. However, the microprocessor was first taken up in a large scale for the production of PCs and not mainframes or even for the production of the technology for which it was first designed- electronic calculators. The very term *Personal* Computer indicates the social dimension of this particular technological artifact. It is a technology for individual use. Its very definition has a social connotation and it would be meaningless to try and understand it in purely technical terms. One of the best metaphors that I know to "explain" the PC was given by one of the founder members of Apple when he was describing how they came upon the concept of the Macintosh: "For the price of a passenger train you can build 1000 Volkswagens. Yes, they don't go as fast, but you can go where you want to when you want to". Seen in this way, the personal computer is not at all the product of a purely scientific and technical evolution, but the product of a firm's response to a socio-economic "need" or what the economists call "the market"[2].

Science and Technology v. Society

In this way we have arrived at one of the central debates of Science, Technology and Society studies: how much of technological change is due to previous scientific and technological change (expressed in the economics of innovation as *science or technology-push)* and how much of it is a response to socio-economic needs *(demand-pull* in the economics of innovation).

The simplistic linear model science-technology-society which we developed and then so easily criticised is more of polemical caricature of the way the science, technology and society relationship is often implicitly portrayed in popular literature and in the purely technical history of science and technology, rather than an accurate reflection of real positions taken by theoreticians of technical change. Nevertheless in the theoretical

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2. I don't wish by this to imply agreement with the proposition that all (or even the most fundamental) human "needs" are expressed by the market. The market can only express "needs" In the form of choices compatible with a given buying power in a particular set of social circumstances.

debates it is possible to differentiate the positions of those who prioritise *science and technology* over *society* from those who do the opposite.

In economics the debate has normally been couched in terms of "science/technology push" v. "demand-pull". Insofar as one can speak of neo-classical economic theories of technical change, these have tended to be of the pure "demand-pull" kind[3]. Whilst such theories cannot in any way be seen as related to the more recent sociological "social constructivist" theories, they do implicitly at least envisage "social need", as expressed through the mechanism of the market, to be the main source of technical change. In contrast, in the economics of innovation developed in the work of economists heavily influenced by the ideas of the Schumpeter, such as Freeman, Dosi, Nelson and Winter[4], *science and technology* are generally seen as relatively autonomous of society and more important as the source of technical change. It is an economic model in which *technology-push* is seen to have priority over *demand-pull.* The relationship with the work of Schumpeter operates at two very different levels of analysis. At the broad societal level, it draws on the long-wave theory of technological change developed by Kondratiev, Schumpeter and others, according to which history is punctuated by economic waves caused by the diffusion throughout society of a cluster of key innovations giving rise to period of strong economic growth. According to this model we are now entering the fifth Kondratiev wave, driven by the convergence of computer and communications technologies At the level of the firm, the neo-Schumpeterian approach sees innovation as a product of the firm's[5] capacity to generate new technologies in the anticipation of being able to enjoy, for a period at least, monopoly profits derived from sole ownership of these new technologies. In this model, technology-push predominates in the early stages of a radical innovation; as a technology matures and society becomes more aware of its potential, demand-pull factors take over.

A neo-Schumpeterian approach to the Personal Computer as innovation, would stress the fact that the founder members of the firms that pioneered the microcomputer (or, before that, the transistor, the IC or the microprocessor) were scientists and technologists profoundly aware of the potentials of the new technologies that were being developed long before any specific applications had been produced who were prepared to take risks and actively develop the markets.

Even in these approaches, it would be wrong and over-simplistic to assume that the role of *society* is absent. For instance, the model of technological change developed by Dosi and by Nelson and Winter sees scientific advances as giving rise to a whole gamut

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3. The classic critique of such theories was undertaken by D Mowery and N. Rosenberg (1979) 'The Influence of Market Demand upon Innovation: A Critical Review of of Some Recent Empirical Studies' Research Policy

4. See for instance C. Freeman (1982) The Economics of Industrial Innovation, Pinter or C. Freeman "The Case for Technological Determinism" in R. Finnegan et al (1987) Information Technology: Social Issues, Open University Press; G. Dosi (1984) Technical Change and Industrial Transformation, Macmillan; R.R. Nelson and S.G. Winter (1982) An Evolutionary Theory of Economic Change, Harvard University Press

5. In the early version of Schumpeter's analysis this was the firm's understanding was synonymous with that of the entrepreneur.

of technological potentialities and society as selecting from amongst these various possibilities those that will succeed:

> ".... the hypothesis is that along the stream science-technology-production, the 'economic forces' together with institutional and social factors operate as a selective *device* (original emphasis)"[6]

The microprocessor, as we have noted above, has a potential for a variety of applications It is the social process of selection which has determined that its greatest use is in the Personal Computer.

A number of authors have given priority to social factors, and see new technologies as being largely "socially-constructed". This point of view has been developed sociologists and historians of innovation such as McKenzie, Callon, Latour and Law, Pinch, Bijker, and Hughes. This "society" is viewed as a complex of organisations, institutions, actors (made up of individuals and social groups) artifacts and technological systems. An understanding of technical change implies an analysis of the complex relationships between these various factors. There are many nuances and differences of emphasis between the various proponents of "social constructivism". However, in opposition to the economists of innovation, they all share a rejection of technological determinism and deny to a large extent any autonomy to the scientific and technical domain.

Whilst the debate is sometimes polarised around issues such as "technological determinism", there is a great deal of common ground between the two schools of thought. In particular they all have in common the concept already introduced previously of society acting as a selection mechanism choosing between a variety of possibilities created by science, or deciding on the success or failure of various innovations which have been made possible by previous scientific developments. This mechanism leads to the setting -up of technological *regimes* (Nelson & Winter), *technological paradigms* and technological *trajectories* (Dosi), technological *frames* (Bijker) or *cultures of* technology (Hughes). This refers to the creation of situations where particular designs, particular way of doing things or solving technological problems become accepted and alternatives automatically excluded. The basic shape of a motor car or a bicycle, the general features of the design of an internal combustion engine or the von Neumann architecture of computers (comprising a central processing unit, memory storing both programmes and data, and input output devices) might all constitute examples of these.

THE LOCUS OF TECHNOLOGICAL CHANGE

Differences begin to emerge when attempts are made to differentiate the various elements which constitute "society" and ascribe to them relative weights in the process of

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6 G. Dosi (1984), op. cit., p.16

technical change. At one extreme of social constructivism, society is a "seamless web" constituted by actor networks "composed of a series of heterogeneous elements, animate and inanimate, that have been linked to one another for a certain period of time"[7]. Bijker introduces "social groups", including technologists and engineers, but denies that any of them should take priority over others. Indeed he argues that 'For a social constructivist analysis of technology, it is important not to make any distinction among different types of social groups'[8]. In the economics of innovation, as we have already noted, the social group which constitutes the technological community has a large degree of autonomy from the rest of society and is the primary locus of technical change. For these re-searchers technological regimes and paradigms are primarily established in this domain. For Bijker, on the other hand, technological frames 'must be applicable to social groups of non-engineers also' and 'should be understood as a frame with respect to technology, rather than as the technologist's frame'[9]. A bridge between the positions is established by Constant[10] who analysis the social loci of technological change and finds it to be pri-marily located in 3 overlapping areas: the *technological community,* the *complex organisation* (ususally corporate) and the *technological system.* The *technological sys-tem* was a concept first introduced by Hughes in his study of development of electrical p o w e r[11]

Another way of approaching the question of the locus of technological change is to consider relative importance of the spheres of production (supply-side factors in econo-mics) and of consumption (demand-side factors). In the economics of innovation, the principal impetus for technical change comes from the sphere of production, which is the where the scientific and technological community is primarily located. As we have alrea-dy noted, in the Schumpeterian analysis it is the firm's capacity to innovate in the expec-tation of monopoly profits which acts as the main motivation for technological change and, within the firm, it is the Research and Development department which is its primary source, ie the principal locus of the "technological community". In most of the "social constructivist" accounts any attempt to generalise on the relative importance of con-sumption and production is seen as an unwarranted prioritisation of factors within the "seamless web". However, Bijker's "social groups" are defined largely in terms of the *mea-*nings which they give to artifacts, a culturalist perspective which implicitly prioritises con-sumption. Constant's attempt to identify firms and technological communities, and tech-nological systems as the primary locus once again establishes a bridge with so-called "technologically deterministic" perspectives.

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7. M. Callon in W. Bijker and T. Pinch, op. cit, p.93

8. Bijker in W E.Bijker, T.P. Hughes and T. Pinch (eds), op. tit, p.171

9. Ibid, pp 171 and 172

10. E. W. Constant in W. Bljker, T.P. Hughes and T. Pinch, ibid

11. T.P. Hughes Networks of Power: Electrification in Western Society, 1880-1930, John Hopkins University Press

The same could be said of Hughes's systems approach which discusses technological change through a detailed analysis of case studies such as of the socio-technical system for production of electric power.

An interesting if somewhat post-modernist recent attempt to use culturalist "social constructivist" perspectives to the analysis of the process of production and thus problematise the question of the relationship between production and consumption (or use) has been made by Steve Woolgar[12].

## THE ANALYSIS OF INNOVATION IN INFORMATION TECHNOLOGY

The analysis of technical change in area of Information Technology provides an ideal scenario in which to try and deploy these analytical tools. The general history of Information Technology and the history of the Personal Computer in particular provides much evidence in favour of both the economics of innovation approach *and* for particular aspects of social constructivism. In the first place, it is difficult to understand the development of microelectronic technology in terms which do not give a certain degree of autonomy to the technical domain. The various stages of miniaturisation (or integration) of electronic circuits had a momentum and an internal technological logic of their own which it would be difficult to understand in terms other than those of Dosi's technological trajectory. Even the transition from the world of the mainframe and mini to the early microcomputers can be understood largely in terms of the quasi-autonomous behaviour of the technological community made up of IT professionals who are located in producer firms, in academic and other institutions involved in IT R&D and within user firms (ie firms which use IT in their production processes) in such areas as data processing or information systems departments. This is a community united by the possession of a common set of technical skills, readership of an overlapping set of literature, possibly membership of professional institutions. They constitute a particular social interest group which have a strong influence in the direction of technical change. The historian and economist of Information Systems, Andrew Friedman[13], has called this "the IT field", using a physical analogy with the concept of "electric" or "magnetic field". The early microcomputers up to and including the Apple II had as its main consumers computer and microelectronic enthusiasts who for the first time were able to own a computer. They could be considered as members of the IT field who broke away from the dominant paradigm and , in doing so, began a technological revolution. Whilst this analysis gives a certain autonomy to the technological domain, the understanding of the reasons why the revolution occurred within the IT field still requires the kind of sociological analysis which is characteristic of social constructivism. Only a detailed understanding of the internal dynamics of the IT

12. S. Woolgar "Configuring the User" in J. Law (1993) A Sociology of Monsters, Routledge

13. A. Friedman "The Information Technology Field: an Historical Analysis" in P. Quintas (Ed), 1993, Social Dimensions of Systems Engineering, Ellis Horwood

field and of the power relations within it can explain the early development of microcomputers Control of mainframe technology was in the hands of the large corporations, the only ones able to afford it. Mainframe computer time was expensive and individual computer enthusiasts were unable to exercise their individual creativity except in the service of the corporation. The advent of the microcomputer changed all this and allowed for the first time the individual technical enthusiast complete control of the technology. Microcomputers also recreated for a short time a world in which the dividing line between production and consumption was greatly blurred. The early makers of microcomputers had much in common with the early buyers in terms of skills and social characteristics. Early microcomputers were sold in kit form, or could be expanded by add-ons which could only be installed by individuals with a great deal of technical knowledge. Early microcomputers could also only be used by people who were able to programme in at least one of the high level languages (usually Basic), but quite often also in machine code or assembly language.

For the understanding of the later development of what became known as the personal computer, we must however go outside the purely technological domain and look at the relationship between the IT field and computer users: ie people (and organisations) who need to use IT as a tool to achieve particular ends and who to a large extent depend on skills found within the IT field for this purpose. This is perceived often as a unwelcome dependence and tensions exist between "users" and the "IT field". This is true both when the "users" are individuals or groups within firms, In order to understand the success of the PC (as a business rather than a home technology), we should return to the Apple founder's metaphor. "For the price of one passenger train, you can build 1000 Volkswagens, Yes, it doesn't go so fast, but you can go where you want to when you want to". Implicit in this metaphor is the fact that the Volkswagen is easy to drive (ie user-friendly) and cheap. Within "user organisations", before the advent of the PC, "users" were dependent on IT professionals for the use of IT (mainframes were the equivalent of passenger trains, and data processing departments the equivalent of railway organisations). The PC made the technology directly accessible to users both in terms of skill (through the development of off-the-shelf packages) and of price. It was produced by IT specialists who broke with the dominant paradigm of the IT field (mainframes and networked minis) through a perception of the existing tensions between users, potential users and existing IT professionals and of the economic potential of the new technologies to exploit these tensions to create new markets. Nowhere is this better expressed than in the famous Apple advert which portrayed IBM in 1984-Orwellian terms as Big (corporate) Brother out to totally control the individual. The implicit message was that Apple was the defender of individual user need- the builder of the IT equivalent of the people's car- the Macintosh- which would liberate him (rather than her) from the tyranny of (IBM-allied) data processing departments.

Fig 1. The IT field
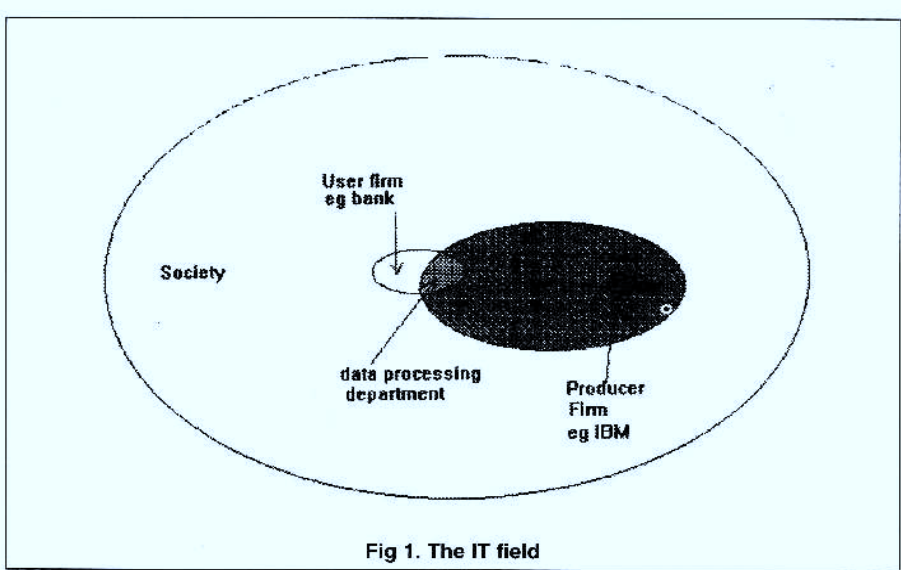
CONCLUSION

The rhetorical question asked at the beginning was used as a device with which to map out some of the broad approaches to the question at the centre of the STS studies: "What is the nature of the relationship between Science, Technology and Society?". We have argued that "science-technology-push" approaches which ascribe a degree of independence to scientific and technological change from society and see science and technology as the main source technological change were dominant in certain strands of the economics of innovation; that these could be contrasted with the "social constructivist" school which prioritised social over technical factors, and which sees society as the main source of innovation. Social constructivism also denies that any particular component of "society" should be given any kind of privileged position over the others.

An approach has been devised which uses social constructivist perspectives but which permits a certain degree of independence to the technical domain and, in certain circumstances, actually prioritises developments in this area as the primary source of innovation. In the case of Information Technology the IT field, a concept first introduced by the historian and economist Andrew Friedman, has been postulated as the primary locus of technical change. The claim has been made that the application of social constructivist methods of analysis to the IT field could provide an explanation for the development of the Personal Computer.