Cambridge Journal of Economics 2010, **34,** 63–76
doi:10.1093/cje/bep068
Advance Access publication 11 November 2009

How is technology made?—That is the question!

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This article reviews constructivist technology studies, and especially the social construction of technology (SCOT). To investigate how these constructivist studies regard the ontology of technology, I will trace their historical development in units of analysis, methodological approaches and research questions. Constructivist technology studies are relativistic in only one sense: methodological. They are agnostic with respect to the ontology of technology. Constructivist studies of technology thus do not primarily answer the question 'what *is* technology?'; they trace the process 'how to *make* technology'.

Key words: Social construction, Ontology, Relativism, Realism, Idealism, Technology, Technological culture, Technological frame
JEL classifications: O30, O31, O33

1. Introduction

As an engineer-turned-sociologist I am less interested in the philosophical question 'What *is* technology?' than in the technical question 'How to *make* technology?', the political question 'How to *use* technology?' and the scholarly question 'How to *study* technology?'. I do acknowledge, however, that there are always implicit or underlying ontological assumptions about technology that one makes while answering these questions. In this article I will, for once, try to do both, giving my answer to the philosophical question about the ontology of technology by addressing the question of how to study, make and use technologies. To be more precise, I will address two distinct (although related) ontological questions in this paper. The first of these questions is 'Are constructivist technology studies necessarily committed to a non-realist (e.g. idealist) view of reality or are they equally compatible with realism?'. The second is 'What is meant by technology in constructivist technology studies?'. My answers will relate to the social studies of technology, and more specifically to the social construction of technology (SCOT). In other words, I will address these ontological questions by an anthropological-historical approach. By tracing the various ways in which sociologists (and historians) have studied technology I hope to gain insight in the underlying ontological assumptions.

Manuscript received 9 April 2009; final version received 21 August 2009.
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* Maastricht University. I thank the editors of this special issue, Rein de Wilde, and two anonymous referees for their helpful comments.

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SCOT began development in the early 1980s, and I will trace its development by following three story lines. The first relates to changes in the unit of analysis—from artefact to technological culture. The second line reviews central methodological heuristics and theoretical claims—from social construction of technology to co-production of technology and society. And the third, parallel, storyline recounts a development in research questions—from understanding the development of technology to questioning the politics of modern technoscientific societies.

Let me start by indicating my answer to the first ontological question before embarking on the three lines of developmental story telling. I will argue that the underlying assumption of social constructivist studies of technology is relativistic. It is helpful in this context to distinguish three forms of relativism—philosophical, methodological and ethical—and I will argue that constructivist technology studies are only relativistic in the methodological sense.[1] The three forms of relativism will return below in the three core sections of this article—on the units of analysis, the heuristics and the research questions.

Only the first form of relativism takes an ontological stance with respect to the realism/idealism question. This philosophical relativism is most easily associated with an idealist position in opposition to realism. Although in everyday usage 'realism' is often used as a name for a low-ambition attitude and 'idealism' is taken to be the more ambitious if not utopian view, in philosophy it is the other way around. 'Realists tend to claim more than their opponents—they are the philosophical optimists' (Mäki, 2001, p 12,815) Realists make claims about the existence of the world, phenomena, universals, abstract objects. Idealists regard things as creations of the minds of observers. I will argue that constructivist technology studies can be *agnostic* about this idealism–realism question: both ontological positions are compatible with constructivist sociology of technology, and the sociology of technology cannot provide empirical arguments to choose for either ontological position. Methodological relativism is the key characteristic of the social construction of technology. As I will discuss in the section on methodological heuristics, this implies a specific form of being relativistic with respect to how the working of a machine is explained. Nothing in the sociology of technology obliges one to accept ethical relativism. I will argue (especially in the section on research questions) that normative and political issues can be fruitfully analysed by using SCOT and that using this conceptual framework can help to formulate one's ethical position. So SCOT does not compel you to be an ethical relativist but neither does it force you to take a particular normative stance.

Whatever my reservation at the beginning of this paper about answering the question 'What is technology?', we do need at least an intuitive answer to this second ontological question too. This preliminary answer is the same as MacKenzie and Wajcman (1985) give in the introduction of their path-breaking reader. Technology comprises, first, artefacts and technical systems, second the knowledge about these and, third, the practices of handling these artefacts and systems. This preliminary answer allows us to embark on doing and discussing *technology* studies, and find out whether we possibly may give a different or more complicated answer to this second ontological question.

2. The sociology of technology and SCOT in particular—a brief introduction

The phrase 'social construction' was first used by Berger and Luckmann (1966) in their 'treatise in the sociology of knowledge'. Building on the phenomenological tradition and particularly on the work of Alfred Schutz (1943) they argue that reality is socially

[1] For a similar argument about constructivist science studies, see Collins (2005).

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constructed and that these processes of social construction should be the object of the sociology of knowledge. Berger and Luckmann focus on the social construction of ordinary knowledge of the sort that we use to make our way about society. They are concerned with the reality of social institutions and their focus is on society at large, rather than on subcultures such as science and technology. Nevertheless, scholarship developed around such themes as the social construction of mental illness, deviance, gender, law and class. Similarly, in the 1970s the social construction of scientific facts developed, followed in the 1980s by the social construction of artefacts.

Constructivist studies of science and technology come in a wide variety of mild and radical (Sismondo, 1993). The mild versions merely stress the importance of including the social *context* when describing the development of science and technology. Examples of such work in technology studies are Constant's (1980) account of the turbojet revolution, Douglas' (1987) history of radio broadcasting, Nye's (1990) studies of the electrification of America, and Kranakis' (1997) history of French bridge engineering. Though never explicitly discussed, it is fair to say that these authors assume a realist ontology of technology. The radical versions of constructivism argue that the *content* of science and technology is socially constructed. In other words, the truth of scientific statements and the technical working of machines are not derived from nature but are constituted in social processes. Radical constructivist studies of science and technology share the same background, have similar aims, and are even being carried out by partly the same authors (Barnes and Bloor, 1982; Bijker, 2001; Collins, 1985, 2001).

The social construction of technology grew out of the combination of three distinct bodies of work: the early science-technology-society (STS) movement, the sociology of scientific knowledge and the history of technology. The first started in the 1970s, mainly in the Netherlands, Scandinavia, the UK and the USA. Its goal was to enrich the curricula of both universities and secondary schools by studying issues such as scientists' social responsibilities, the risks of nuclear energy, the proliferation of nuclear arms, and environmental pollution. The movement was quite successful, especially in science and engineering faculties, and some of the STS courses became part of the degree requirements. The sociology of scientific knowledge (SSK) emerged in the late 1970s in the UK on the basis of work in the sociology of knowledge, the philosophy of science and the sociology of science (Bloor, 1976; Collins, 1981, 1985). The central methodological tenets of the strong programme (especially its symmetry principle) seemed equally applicable to technology. In the history of technology, especially in the USA, an increasing number of scholars began to raise more theoretical and sociologically inspired questions (influential were Hughes, 1983, and Cowan, 1983). Path-breaking advocacy for this body of work in the history of technology provided the reader edited by MacKenzie and Wajcman (1985).

Researchers from these three traditions convened in an international workshop in 1984 in the Netherlands. The subsequent volume from that workshop, edited by an STS-er, a historian of technology and a sociologist of scientific knowledge (Bijker *et al.*, 1987), has been heralded as the starting point of the social construction of technology. To understand the role of this workshop and volume, it is helpful to distinguish between a broad and narrow usage of the phrase 'social construction of technology' (but note that both notions fall within the radical meaning of social constructivism). When broadly used, 'social construction of technology' encompasses all the work represented in the 1987 volume, including the actor-network approach by Callon, Latour, Law (e.g. Callon, 1986, 1987, 1995; Latour and Basite, 1986; Law, 1986) and the technological systems approach by

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Hughes. Used more narrowly, it refers primarily to the programme set out by Pinch and Bijker (1984) and denoted by the acronym SCOT.

3. The sociology of technology and its unit of analysis

In the early days of SCOT, the unit of analysis was the single artefact. The choice for the artefact as unit of analysis was a choice for the 'hardest possible case'. To show that even the working of a bicycle or a lamp was socially constructed seemed a harder task, and thus—when successful—more convincing than to argue that technology at a higher level of aggregation was socially shaped. This strategy followed from the need to criticise technological determinism as a view that granted agency to technologies and seemed to deny the possibility to influence the course of technological development (see below). Here SCOT comes close to an idealist ontological position: technical artefacts are analysed by looking at statements uttered by humans, and no assumptions are being made about the existence of these artefacts independently of the statements about them. On the contrary, the symmetry principle is taken as a warning *not* to assume any independent existence of technology when explaining the working of machines.

The analysis of singular artefacts indeed proved fruitful and convincing. Once this fundamental point against technological determinism was made—that technology does not have its own intrinsic logic but is socially shaped, even at the level of a singular machine—the unit of analysis could be 'extended' (see Table 1 for a summary). The first extension, which really formed part of the 'prehistory' of SCOT, was to take the 'technological system' as the unit of analysis. When such a system is taken to be purely a 'technical system' this is a quite trivial move, for there is nothing self-evident about the delineation of even a 'singular' artefact. Is the bicycle an artefact or is it a technical system comprising artefacts such as wheels, saddle, frame, handlebar and brakes? Or is the wheel not an artefact, but a system comprising rim, hub, spokes and tyres? The substantively different move, already made by Thomas Hughes (1983, 1986), happens when it is recognised that a technological system comprises a combination of technical, social, organisational, economic and political elements. If the artefactual unit of analysis allowed the basic point to be made that 'technologies could have been different', this system unit of analysis allowed meso and macro issues that relate to economic and industrial development or regulatory regimes to be addressed in, for example, electrification and transport infrastructures (Hughes, 1987, 2004; Joerges, 1988; La Porte, 1991; Mayntz and Hughes, 1988).

The next unit of analysis—sociotechnical ensemble—is, at first sight, very similar to the technological system. After all, the latter includes technical *and* social elements, and that seems exactly what 'sociotechnical' is meant to invoke. There are two key differences between technological system and sociotechnical ensemble—the first with a theoretical edge, the second with (yes, why not...) an ontological. Using the word 'system' to denote a unit of analysis inevitably entails the usage of some form of systems theory, with the associated cybernetic engineering or Luhmann-style (1990) conceptual framework. The

Table 1. *Different units of analysis*

Singular artefact (technical system)
Technological system
Sociotechnical ensemble
Technological culture

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word 'ensemble' is conceptually less restrictive and allows for a broader, more open—some would say more messy—range of conceptual approaches. The second difference is highlighted by the words 'technological' and 'sociotechnical' and builds on the symmetry principle. The symmetry principle extends the metaphor of 'seamless web', which was at the core of Hughes's technological systems approach. In that context, the phrase 'seamless web of technology and society' is used as a reminder that non-technical factors are important for understanding the development of technology. A second, more sophisticated meaning is that it is never clear *a priori* and independent of context whether an issue should be treated as technical or social. Was the Challenger accident a technical failure, an organisational mistake or primarily a lack of adequate funding (Vaughan, 1996)? The recognition that all kinds of social groups are relevant for the construction of technology (unit of analysis: artefact) and that the activities of engineers and designers are best described as heterogeneous system building (unit of analysis: technological system) supports this second usage of the seamless web metaphor. The third interpretation of seamless web links it to the symmetry principle. The 'stuff' of the fluorescent lamp's invention is economics and politics as much as electricity and fluorescence. Let us call this 'stuff' sociotechnology. The relations that play a role in, for example, the development of the fluorescent lamp are thus neither purely social nor purely technical—they are sociotechnical (for the lamp case, see Bijker, 1995; for the general symmetry principle, see Callon, 1986).

A brief ontological note may be helpful at this point. The statement that the fluorescent lamp 'is made of sociotechnical stuff' can be read in various ways (Mäki, 2001). A realist reading would imply that the lamp exists, that sociotechnical stuff exists, and that the first is made of the latter: the basic paradigm is that physical reality existed before there were any humans around. A phenominalist reading would say that sense data exist, and create an image of the lamp, the stuff and their relation; but phenomenalism makes no claims about what generates the sense data. An idealist reading would claim that the lamp and the stuff exist as ideas, as does the description of the lamp being made of that stuff: there is no existence of lamp or stuff or their relation independently of human minds. All three readings are compatible with the methodological relativism of constructivist technology studies.

The final unit of analysis that I will discuss is 'technological culture'. Extending the social constructivist arguments that were made with the use of the previously discussed units of analysis, we can now start asking questions about society and culture at large. Today's societies, we then assume, are thoroughly technological and all technologies are pervasively cultural. Technologies do not merely assist in everyday lives, they are also powerful forces acting to reshape human activities and their meanings. The introduction of a robot in an industrial workplace not only increases productivity, but may radically change the process of production and thus redefine what 'work' means in that setting. When a sophisticated new technique or instrument is adopted in medical practice, it transforms not only what doctors do, but also the way people think about health, illness, medical care and even death. And coastal defence (by which I mean dikes and levees) in the Netherlands and the USA mirror the differences in risk culture in both countries (Bijker, 2007). In sum, we live in a technological cultures.

Although I present these units of analysis as historically developing out of each other, this does not imply that the earlier ones are outdated. The units of analysis can exist next to each other, and should be chosen to match the research question that one is addressing. Within a larger study it is even quite likely that different units of analysis will be used in parallel. Analysing the innovative developments of the system of rice intensification (SRI) necessarily

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implies an analysis of the artefact of a mechanical weeder, the technological system of irrigation and the technological culture of rural India (Prasad, 2006; Prasad *et al.*, 2007).

4. The sociology of technology and its central methodological heuristics and theoretical claims

As a set of heuristics for studying technology in society, the social construction of technology can be laid out in three consecutive research steps (Bijker, 1995). Let me introduce these by concentrating on the early version of SCOT, when the unit of analysis was the technological artefact.

Key concepts in the first step are 'relevant social group' and 'interpretative flexibility'. An artefact is described through the eyes of relevant social groups. Social groups are relevant for describing an artefact when they attribute explicitly a meaning to that artefact. Thus, relevant social groups can be identified by looking for actors who mention the artefact in the same way. For describing the high-wheeled 'ordinary' bicycle in the 1870s such groups were, for example, bicycle producers, young athletic 'ordinary' users, women cyclists and anti-cyclists. Because the description of an artefact through the eyes of different relevant social groups produces different descriptions—and thus different artefacts—this results in the researcher's demonstrating the 'interpretative flexibility' of the artefact. There is not one artefact, but many. In the case of the 'ordinary' bicycle: there was the 'unsafe' machine (through the eyes of women) and there was the 'macho' machine (through the eyes of the young male 'ordinary' users). For women the bicycle was a machine in which your skirt got entangled and from which you frequently made a steep fall; for the 'young men of means and nerve' riding it, the bicycle was a machine to impress lady-friends. This is the central idea of the methodological relativism that SCOT advocates: do not assume any *a priori* preference for one relevant social group over another. Truth of statements as well as the working of machines can be analysed and explained within one frame, but there is no hierarchy of frames: there is no way of determining that one frame of interpretation is better than others (Hacking, 1982).

Such methodological relativism will help to avoid prioritising winners over losers, successful machines over failing ones, the working of technology over the non-working. Instead, the methodological *dictum* is to follow the social processes and thus empirically find out what makes up well-working, success and winners. The focus is more on understanding the process than on describing the product.

Let me again stop at this point to make an ontological note. Phrases like 'there is not one artefact' and 'there are many artefacts' can, again, be read in realist, phenomenological or idealist ways. These statements are not ontological, implying a realist existence of artefacts without human and social processes (or, alternatively, a phenominalist existence as sense data or an idealist existence as ideas). They are theoretical propositions making claims about how the development of artefacts in relation to social processes is best understood. The argument is that analysing the development of the bicycle in terms of a competition between the macho bicycle and the unsafe bicycle does a better explanatory job than telling the story as a linear development of one bicycle, albeit with a variety of interpretations.

Let us return to the SCOT heuristics to study technology. In the second step, the researcher follows how the interpretative flexibility diminishes, because some artefacts gain dominance over the others and meanings converge—and in the end one artefact emerges from this process of social construction. In the beginning of that process one needed to use

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descriptions such as 'Lawson bicyclette', 'Star bicycle', 'safety ordinary', 'Dwarf Safety Roadster', 'Rover Safety bicycle'; by the end of the stabilisation process just saying that one had seen a 'bicycle' was unambiguous enough. Here, key concepts are 'closure' and 'stabilisation'. Both concepts are meant to describe the result of the process of social construction. 'Stabilisation' stresses the process character: a process of social construction can take several years in which the degree of stabilisation slowly increases up to the moment of closure. 'Closure', stemming from SSK, highlights the irreversible end point of a discordant process in which several artefacts existed next to each other.

In the third step, the processes of stabilisation that have been described in the second step are analysed and explained by interpreting them in a broader theoretical framework: why does a social construction process follow this way, rather than that? The central concept here is 'technological frame'. A technological frame structures the interactions among the members of a relevant social group, and shapes their thinking and acting. It is similar to Kuhn's (1970) concept 'paradigm' with one important difference: 'technological frame' is a concept to be applied to all kinds of relevant social groups, whereas 'paradigm' was exclusively intended for scientific communities. A technological frame is built up when interaction 'around' an artefact begins. In this way, existing practice does guide future practice though without logical determination. The cyclical movement thus becomes: artefact–technological frame–relevant social group–new artefact–new technological frame–new relevant social group, etc. Typically, a person will be included in more than one social group and thus also in more than one technological frame. For example, the members of the Women Advisory Committees on Housing in the Netherlands have an inclusion in the technological frame of male builders, architects, and municipality civil servants—this allows them to interact with these men in shaping public housing designs. But at the same time many of these women are included in the feminist technological frame, which enables them to formulate radical alternatives to the standard Dutch family house that dominates the male builders' technological frame (Bijker & Bijsterveld, 2000).

This three-step research process to analyse the development of artefacts thus amounts to: (i) sociological deconstruction of an artefact to demonstrate its interpretative flexibility; (ii) description of the artefact's social construction; and (iii) explanation of this construction process in terms of the technological frames of relevant social groups (see Table 2). It is important to appreciate that the social construction of technology provides a set of research heuristics for interpretative sociology; it is not an empiricist fishing net to catch empirical facts. The adage 'identify all relevant social groups by searching citations of the artefact by a variety of actors', for example, does not diminish the researcher's task to

Table 2. *Units of analysis with associated key concepts*

Unit of analysis	Key concepts
Singular artefact (technical system)	Relevant social group Interpretative flexibility Stabilisation and closure Technological frame
Technological system	Technological momentum
Sociotechnical ensemble	Closed-in hardness Closing-out obduracy
Technological culture	Co-production

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decide which groups are important to include in the account, and which groups only obfuscate the picture by adding useless details.

The constructivist analysis thus provides a theoretical perspective on both the social construction of technology and the technological impact on society. It offers a reconciliation of the previously opposite social constructivist and technological determinist views. This reconciliation asks for a theoretical elaboration, extending the conclusion of the previous section: that the distinction between technology and society can be transcended and that the subject matter for analysis is sociotechnology. The concept 'technological frame' provides the theoretical linking pin between the two views. A technological frame describes the actions and interactions of actors, explaining how they socially construct a technology. But since a technological frame is built up around an artefact and thus incorporates the characteristics of that technology, it also explains the influence of the technical on the social. Part of the societal impact of the standard Dutch family house was that it dominated architectural thinking in the 1950s and through to the 1970s, and thus made it very difficult to conceive alternatives: architects and even members of the critical Women Advisory Committees were 'closed-in' by the technological frame of the two-parents-two-children-house.

The concept of 'technological momentum' is also used to give an historical and constructivist account of technological determinist phenomena, but in combination with the unit of analysis 'technological system'. When a technological system grows by investments in capital, technology and people, it builds up technological momentum—it seems to acquire a certain directional development and speed. As a result of all of those investments, it becomes more and more difficult to change its course and the system starts to have increasing impact on its environment: exactly the characteristics that technological determinism captures.

Using the sociotechnical ensemble unit of analysis to address questions about the impact of technology on society (see next section), other concepts are needed than used for the analysis of artefacts' development—we need to conceptualise the hardness or obduracy of technology, rather than their malleability and interpretative flexibility. An artefact can be hard in two distinctly different ways (Bijker, 1995; Hommels, 2005). The first form, 'closed-in hardness', occurs when the humans involved have a high inclusion in the associated technological frame. For example, students well versed in the use of mobile phones will react differently to a malfunctioning cell phone than the old-fashioned author of this article. The student may start modifying the network selection, switch the battery, or tinker with the preferences menu. Only after some time will it occur to her that she could also look for a landline phone: she was 'closed-in' by the mobile phone technology. The author of this article, when confronted with a non-working cell phone, might try to ring a second time but then would probably soon give up and look for a landline phone or write a letter. He can barely locate the power switch, and experiences the second kind of impact by technology: 'closing-out obduracy'. He sees no alternative but to leave the technology aside and pick up his fountain pen. In both cases the technology has an impact on these people, but in completely different ways.

These two forms of hardness of technology can also be seen on the societal level. The automobile technology, for example, exerts a 'closed-in hardness' on the inhabitants of Los Angeles: much differentiation within the auto culture and hardly thinking of alternatives outside it. The standardisation of main power voltage and wall plugs implies a 'closing-out obduracy' to most people: no differentiation by tinkering with transformers and plugs but complete acceptance by buying the right plug and apparatus, or by not using electricity at all.

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The unit of analysis of technological culture does away with social factors and technical artefacts. In other words, technical reductionism and social reductionism—or technical determinism and social construction—are both impossible as explanatory strategies. Instead, new forms of explanation need to be developed. This is where concepts such as 'co-evolution' or 'co-production' come in.

Co-production is shorthand for the proposition that the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it. Knowledge and its material embodiment are at once products of social work and constitutive of forms of social life. (Jasanoff, 2004, p. 2)

The idea is to explain the developments of society and technology as two sides of the same coin. This borders on thick description and answering 'how' questions, rather than answering 'why' questions with clearly explicated causal chains.[1]

5. The sociology of technology and its key research questions

An important, though negative, starting point for the social construction of technology was to criticise technological determinism. Technological determinism was taken to comprise two elements: (i) technology develops autonomously, and (ii) technology determines to an important degree societal development. This view was seen as intellectually poor and politically debilitating. Technological determinism implies a poor research strategy, it was argued, because it entails a teleological, linear and one-dimensional view of technological development. And it was considered politically debilitating because technological determinism suggests that social and political interventions in the course of technology are impossible, thus making politicisation of technology a futile endeavour. To bolster this critique on technological determinism, it was necessary to show that the working of technology was socially constructed—with the emphasis on *social*. The research question, then, was to understand the development of technical artefacts in other terms than technology's own internal logic (see Table 3). This is why constructivist studies of technology better avoid a realist ontology: a realist view would easily allow (though not oblige) technological determinism to enter through the back door again.

The agenda of demonstrating the social construction of artefacts by an analysis at the micro level resulted in a wealth of case studies. A few years later, the research programme was broadened in two ways (Bijker and Law, 1992). First, questions were raised at both meso and macro levels of aggregation—for example about the political construction of radioactive waste, clinical budgeting in the British National Health Service or technically mediated social order. Second, the agenda was broadened to include the issue of technology's impact on society, which had been bracketed for the sake of fighting technological determinism.

After successfully criticising technological determinism and again asking the question—though in different terms—of the impact of technology on society, the development of social institutions as constituted by technology also came to the agenda. The social fabric of society may be kept together by church, capital, government, labour, communication, education,

[1] By describing this work as 'studying the interaction between technical and social factors', one of the anonymous reviewers suggesteded that this trend be interpreted as a convergence of realist and constructionist positions. I do not want to do that. Such a characterisation dilutes the clear constructivist unit of analysis and methodology by unnecessarily assuming a realist position on the existence of technical and social entities. For the same reason I see no need to conceptualise technologies as having a 'dual nature' of social function and physical form (Faulkner and Runde, 2009; Kroes and Meijers, 2006).

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Table 3. *Units of analysis with associated research questions*

Unit of analysis	Research questions
Singular artefact (technical system)	How can we describe and understand the development of technology in non-internalist terms?
Technological system	How to understand the development of large technological systems? How to understand the impact of technology on society?
Sociotechnical ensemble	How to understand social order? How to understand the relation between the social shaping of technology and the technical building of society?
Technological culture	How to understand normative and political issues in technological societies?

etc., but where would all of these be without technology? Social order in modern society can only be explained by reference to technology (Latour, 1992). In SCOT this is done by conceptualising the hardness or obduracy of technology, as was discussed in the previous section.

We live in a technological culture: our modern, highly developed society cannot be fully understood without taking into account the role of science and technology. The social construction of technology offers a conceptual framework for politicising this technological culture. ('Politicising' here means: showing hidden political dimensions, putting issues on the political agenda, opening issues up for political debate.) The social construction of technology approach not only gives an affirmative answer to Winner's (1980) question 'Do artefacts have politics?', but also offers a handle to analyse these politics (Bijker, 2006). Technology is socially (and politically) constructed; society (including politics) is technically built; technological culture consists of sociotechnical ensembles.

Studies that elaborate this agenda draw on constructivist technology studies in the broad sense. One of the most fruitful bodies of work is the analysis of gender and technology (Lerman *et al.*, 1997; Wajcman, 2004, 2005). Another now quickly expanding domain of research focuses on the politicisation of information society and information and communication technologies (see Schmidt and Werle, 1998, for a fruitful approach via standardisation issues). Studies like MacKenzie's (1990) history of guided missiles, Hecht's (1998) history of nuclear power in France, and Vaughan's (1996) account of the Challenger disaster demonstrate that the new framework can be productive for the analysis of classical political research questions too.

The issue of political decision-making about technological projects acquires a special guise under the light of the social construction of technology. If it is accepted that a variety of relevant social groups are involved in the social construction of technologies and that the construction processes continue through all phases of an artefact's life cycle, it makes sense to extend the set of groups involved in political deliberation about technological choices. Thus, several countries experiment with consensus conferences, public debates and citizens' juries. One of the key issues here is the role of expertise in public debates. The social construction of technology approach suggests that all relevant social groups have

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some form of expertise, but that not one form—for example the scientists' or engineers'—has a special and *a priori* superiority over the others.

The developments I have sketched do not only influence the question of 'how to study technology?', but also allow one to address the making and using of technologies. Increasingly, social students of technology are involved in technology development itself. An early and well-known example is Lucy Suchman's (1987) work at Xerox, but a variety of recent studies argue to extend the goals of technology studies to also include engagement and intervention in addition to understanding (Bijker, 2003; Woodhouse *et al.*, 2002; Zuiderent-Jerak, 2007).

Many of the research questions discussed above involve normative and political issues. Thus, evidently, the social constructivist sociology of technology in its early (narrow) form did not preclude addressing normative questions, and in its later (broader) form is all about raising and addressing such issues. I can only explain the occasional misunderstanding, by, for example, Russell (1986) and Winner (1993), on the basis of misreading *methodological* relativism for a form of *ethical* relativism (see also Hamlett, 2003). My own research at this moment is, for example, primarily concerned with the vulnerability of technological cultures and the role of science and technology for development. This research is explicitly connected to normative choices and political engagement (Bijker, 2009).

6. Conclusion

My purpose was to discuss the ontological assumptions of the (constructivist) sociology of technology by tracing the developments in units of analysis, methodological approaches and research questions. On the first ontological question—about the idealist/realist stance of constructivist studies of technology—I have argued that three different forms of relativism can be distinguished, of which only the first one—philosophical relativism—implies an ontological stance on this issue. The earliest version of SCOT comes close to adopting a social realist position in its focus on relevant social groups and in using social processes as *explanans*, while arguing explicitly against the technologically realist view implied by technological determinism.[1] But since that early form of SCOT describes technologies through the statements (ideas) of humans in social groups, it could also be labelled as idealist. So, again, all forms of SCOT are agnostic with respect to the ontological status of technology and the natural world: you need not take any ontological position as a researcher to use SCOT for studying technology, nor does SCOT have any bearings on the ontological status of technology.

On the second ontological question, 'what is meant by technology in constructivist technology studies?', I started out with the preliminary answer of: artefacts, knowledge and practice. We have come further now. The methodological relativism allows us to *address as technologies* many 'things' that normally are not considered as technologies. Examples are cities (Aibar and Bijker, 1997; Hommels, 2005), economic markets (Pinch and Swedberg, 2008) and even parents and children (Thompson, 2005).

The key characteristic of the constructivist sociology of technology is its methodological relativism: that for explaining the development of technology no special status is awarded to power (of social groups), success (of projects), truth (of propositions) or working (of machines). The associated research heuristics advises the researcher *not* to use the working

[1] Similarly, Collins (2005) argues that his own sociology of scientific knowledge implies a social realist position.

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of a machine as an explanation of its success, but to trace this success as resulting from social processes. This methodological relativism combines well with ontological agnosticism on the realism/idealism question. It also allows a non-essentialist answer to the second question by exploring how technology is *made and used*, rather than what it essentially *is*.

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