1 Why Rethinking?

The Debates and the Argument

Two ideas about science, technology, and social change have dominat
social sciences for some time; both, I will argue in this book, mistake
is what I will call "speculative" scientific and technological determinis
idea that science and technology cause wholesale changes in society.
the view, for example, of those who argue that we live in an informa
knowledge society, or that science and technology have revolutionized
ciety we live in today. It is also a view that is out of fashion among resea
though it is widely held in society at large and often propounded in p
writings on science and technology.

The other is the idea that science and technology never determine
change in and of themselves or independently, but that this change
ways already cultural or social. On this view, science and technology
escapably part of a social context, and therefore no autonomous role in
change can be attributed to them. This view, known in the subdiscipline
sociology of science and technology as "social shaping" or "social con
tivism," is currently so well entrenched among academic researchers
can be labeled an orthodoxy. This view also has a widely held counter
society at large, as in the saying that "it is never science (or technology
that causes change, it is people."

must surely lie somewhere between these two extremes, or that the
must have been posed incorrectly to lead to such contradictory views
say at this stage is that the formulation is not at fault, and that the an
will be given here does not lie somewhere halfway between the two
Briefly, my argument will be that scientific and technological dete
is true, but not in the wholesale way that (speculative) determinists
believe. Instead, determinism needs always to be yoked to the evide
specific social changes that science and technology—independent
about. Put in a nutshell, the view I shall argue for here is that sc
technology *do* determine social change, but from a social science pe
their role in society is never independent of *what* they do to change
ral and social worlds.

This book will put forward several new arguments about the rel
between science, technology, and social change. I list the main ones
will elaborate the first two in the introduction and the others in later
assessing—and amassing—the evidence to support them along the w

1. Science, following Ian Hacking, is defined as "representing an
vening," and I add to this my definition of technology as "refin
manipulating." These are realist definitions that postulate that
edge and the world are separate, as are artifacts and the enviro
they shape, which makes the main task of social science to ana
how the two sides interlock.
2. The social side of science, following Max Weber, is disenchan
and technology extends this disenchantment into the social w
creating a cage of relations mediated by artifacts. Science and
ogy are cumulative, and disenchantment resulting from the g
of scientific knowledge is therefore progressive and displaces
forms of culture, while technology imposes an ever more pow
human footprint on the environment.
3. Science and technology are separate from culture, as well as
political and economic spheres. Without this separation, it is
sible to grapple with the distinctiveness of modern science: a
historically unique trajectory of cumulative knowledge that f
the wake of the distinctive science-technology entwining in t

and these new patterns of social change must come from compa
tive history: macrohistorical comparison with premodern socie
pinpointing where and when the takeoff of science/technology a
economic growth took place, and the more specific stages in wh
subsequently did so.

4. Comparative history also provides two concepts that explain th
tinctiveness of science and technology in the twentieth century-
science and large technological systems—which increase their s
and scope, and thus also increase their entwining with other ins
tions and their imprint on the environment. Recent history also
lows us to chart the shift toward—and limits to—a global innov
system.

5. The most obvious impact of science and technology is via econo
growth, but to gauge the significance of science and technology
everyday life, it is not enough to look at purely quantitative eco
effects. Their advance must also be translated into the use of tec
gies in everyday life. Mass production and mass consumption h
vastly extended the reach and volume of goods and services. Th
pact of technology—and more indirectly of science—on everyda
is thus to lead to a proliferation of technologically mediated acti
that leads to ever more homogeneously diversified ways of life.

In the introduction, I will elaborate several of these arguments abo
relation between science, technology, and social change. No attempt
made to provide a systematic review of other ideas about science, techn
and social change—these are readily available elsewhere—except to
critically with them at various points in this book.[1] Still, it is worth sa
bit more about some key debates before plunging into the argument.

The theory of science, technology, and social change in the academic
has in the past two decades been dominated by developments at the fo
of social theory generally, in the 1970s and 1980s by social shaping with
ties to broader (neo-Marxist) debates about economic forces shaping s
and more recently by social constructivism, part of the larger trend o
modernism in the social sciences. These currents will not be discussed
detail except to highlight how the comparative-historical and institutio

The argument of social shaping was directed against the "intern
of thinking about science and technology, which regarded scientif
edge and technological innovation as a succession of ideas and impr
developing in isolation from and independent of their social contex
similar to the way in which the history of culture and ideas as a serie
connected and free-floating thoughts was challenged by more mater
ceptions (see Abercrombie, Hill, and Turner 1980). Against interna
social shaping perspective argued that science and technology cou
divorced from their social contexts, being shaped by dominant po
ests. This perspective became known as the sociology of scientific k
(SSK) or science and technology studies (STS). Constructivism has
this line of thought. The preoccupation with power has of late shift
a concern with meaning and identity in cultural constructivism, wh
ence and technology are "suspended in webs of meaning that stru
possibilities of their action" (Hess 1997: 83) and are therefore not aut
objectively valid, or related directly to material objects. What is co
these positions, and what defines social constructivism, according t
cultural constructivism—constructivism can be used for both he
they are "studies that treat the social world as an exogenous, ind
variable that shapes or causes some aspect of the content of science
nology" (Hess 1997: 82; see also Woolgar 1988). In short, for constr
as for SSK or STS, society shapes scientific knowledge.

These ideas were often first articulated for science, but, as alre
cated in the quote by Hess, they came to be applied to technology as
idea of the social construction of technology was thus also developed
earlier social shaping tradition.[2] If science and technology are alway
ably social, this goes against technological determinism, which is f
criticized by writers in this tradition: "The technological, instead
sphere separate from society, is part of what makes society possible-
words, it is constitutive of society" (MacKenzie and Wajcman 199
can note already that it is curious that technology is constitutive and
separate sphere.[3] Note also that *technological* determinism is criticiz
is never, to my knowledge, talk of *scientific* determinism—thoug
ter seems to be part and parcel of the former. (Instead of *Rethinkin
Technology and Social Change an alternative title for this book co

) a or b?

the dominant perspective of social shaping and constructivism as argu
opposite; namely, that science and technology are always already sha
social and cultural forces or that they are inescapably social and cultur

Apart from this recent postmodern or constructivist theorizing, th
contributions to the study of the role of science and technology have beer
by historical and contemporary case studies of individual areas of scien
technology (often informed by social shaping or constructivism). Ther
also been discussions in research policy about the social implications
scientific discoveries and of individual new technologies. And finally
have been high-powered debates about technology and quantitative me
of economic growth in economic history. We will draw on many of thes
but the problem with these more local, policy-oriented, and quantitativ
ies is that they only cover particular aspects of the science, technology, a
ciety relationship. Put differently, what is lacking in these studies is an
account of science, technology, and social change.

A related problem is that, apart from the sociology of science an
nology, the social sciences have treated science and technology from
their narrowly disciplinary vantage points. Disciplines like philosop
the subdiscipline of the philosophy of science—treat the question of sc
truth as an epistemological issue, whereas others, such as anthropolog
with science under the rubric of "rationality" in society. Or, to take a
example, economics conceives of technology primarily as innovation
a question of productivity or growth, while history or cultural studies
more interested in the symbolic value of a technological artifact. To
pate, I will argue that it is impossible to treat these questions separately
put it the other way around, that it is necessary to answer the philoso
question, what is scientific knowledge?—and the sociological question
science affects social relations—*simultaneously*. Similarly with techn
where innovation is one part of the impact and the everyday cultural
cance another, and neither can be discussed without the other.

Further, and to anticipate a key argument that will be made at leng
necessary to provide a comprehensive theory of the science-technolo
social change relationship, *and* at the same time to take into account
thing that lies outside of this theory, namely, the (comparative-his
and other empirical) *evidence*. In other words, regardless of disciplin

social change theoretically and empirically—rather than dealing wi
ular areas or microcontexts or resting on a priori philosophical assu

The aim of the remainder of this chapter is to present definitions
and technology and suggest how these can overcome some of the im
current debates.

Some Definitions

Before we can proceed with a definition, we need to ask two broad m
questions: One is whether science and technology play a *unique* role i
or industrial society, and the other is whether they have had an *au*
impact on society (as we shall see in a moment, the two are linked). T
ogy of science and technology typically deals only with the second
has been tackled within a number of disciplines, foremost among
tory (Smith and Marx 1994), economic history (Inkster 1991a; Mo
and economics (Rosenberg 1982). The combination of the two ques
raises important issues in philosophy (Trigg 1993: 149–71) and anth
(Horton 1970). Curiously, even though the same questions arise in
disciplines, there is very little interchange between them, and the so
science and technology has been quite insular in focusing on the se
not engaging with the first.

In economic history and comparative historical sociology, th
emerging consensus that the role of science and technology in m
capitalist, or industrial) society has had unique social consequence
comitants (this topic will be treated in more depth in Chapter 4). R
of whether the emphasis is on how science and technology foster
development (Inkster 1991a), or how they produce economic gro
narrowly conceived (Mokyr 1990), economic historians recognize th
fects of the Industrial Revolution in the nineteenth century were a
in the role of science and technology in society. Only at a particu
did science and technology *systematically* become oriented to the
knowledge and economic growth. And only in modern societies, to
a point made by Collins (again, it will be developed later), does sc
come "high consensus rapid-discovery science" (1994: 157). The impo
this is that we can say that science and technology are not everywh

growth during this period, their relation with society changed too.

This much is not controversial—or at least, a variety of types of his analysis would converge on this point if they were directly confronte each other. There continue to be debates about the timing and the s part played by science and technology in the Industrial Revolution two industrial revolutions), to what extent the scientific revolution was condition of the Industrial Revolution, and so forth. These debates co in several disciplines, the most advanced being in economic history we will return to these debates, and to the unique role of modern scien technology, in Chapter 4). My point here is simply that from the point of comparative history, a distinctive trajectory is undeniable.

It is not possible to go directly from this comparative-historical arg to the autonomy of scientific and technological change. The further to say that sustained economic growth is a central feature of modern that sets modern—or again industrial or capitalist—society apart from tional or preindustrial or precapitalist societies (nothing in the argume hangs on the three different labels, so I will use all three as appropriate context). In other words, both are unique, modern science and tech *and* modern sustained economic growth. If we now combine these tw uniqueness of this type of economic growth and the unique growth entific knowledge and of technological development in industrial socie say that there is a causal relationship between them, then there will nev less be an element of circularity in this argument.[4] For the purpose argument, what is required is only a "necessary condition" stipulation not without the other—since we may or may not be able to arrive at sary and sufficient causality across the great divide between premode modern societies.

There may, however, be good reasons for this circularity: if it were the fact that scientific knowledge (and with it, technology of a certain could be separated from nonscientific belief systems in this way, it is d to see how any distinction between science and other kinds of belief s could be made in the first place. Similarly, if the material basis of societi have undergone the transformation of industrialization could not be rated from those that had not, there would be little point in setting m or industrial societies apart at all.[5] Be that as it may, the implication

shall see shortly, bears importantly on how the relation between sc
technology and social change is conceptualized not only on this m
comparative-historical level, but on all levels of social scientific a
including, as we shall see, on the microlevel of everyday life.

The autonomy of science and technology follows at this point s
consequences, at least on this occasion, are different from those elsew
now we need to ask, what is the significance of this autonomy? Mar
that the main importance of science and technology lay in their ca
transform the mode of production, but as MacKenzie has pointed o
too narrow since it leaves out, among other things, domestic tech
military technology (1984: 499, note 84).[6] In any case, if the autono
ence and technology has been established by reference to its associa
economic growth, then it should be the case that the consequenc
autonomy are not merely economic ones.

We shall soon come to the wider implications of these argumen
all I have done is to argue that there is a consensus about the evi
the uniqueness or distinctiveness of modern science and technology
definition must take this into account. But again, it is worth stressin
"must" here has to come from the comparative-historical evidence
the side of the conceptual or theoretical apparatus that we bring to
So we must also ask, how should we define science and technology?
they *do*?

Here it becomes useful to draw on Ian Hacking's discussion o
Hacking contends that modern science "has been the adventure of
locking of representing and intervening" (1983: 146). "We shall coun
he writes, "what we can use to intervene in the world to affect somet
or what the world can use to affect us" (1983: 146).[7] This idea can be
to technology, except that in this case, we are dealing with physica
rather than with knowledge since, as Agassi has pointed out, "at the
. . . the implementation of any technique whatsoever involves both
and social activities" (1985: 25; cf. Bimber 1994: 88). Or, as Price p
one wishes to do something to something, what one uses is a techni
than an idea" (1986: 240). In other words, technological artifacts are
human and the natural or physical environments meet, but technolo
involves (physical) hardware. Paraphrasing Hacking's conception o

the process whereby artifacts are continually being modified in order
hance or extend our mastery of the world.[8] Science is directed at the
or physical world, technology at the physical environment of human be

This is what science and technology, respectively, *do* to the natur
physical world and to the natural and human environment. This adds pr
tism to Hacking's realism. But *what* they do simultaneously has social
Max Weber's ideas can take us further here. What science and techn
do on the social side is a disenchantment by more powerful knowledge
"caging" into our uses of more effective tools: more powerful knowledg
to and displaces other beliefs, while enhanced tools add to and compl
our existing range of tools. Weber regarded science and technology as
to the process of disenchantment, or the increasing extension of instr
tal rationality throughout the social world (Brubaker 1984: 29–35; Sch
1995), which simultaneously creates an "iron cage" of instrumentally r
institutions.[9] Weber was a cultural pessimist about this process; Gellne
a corrective when he calls this a "rubber cage," which is much more
friendly and reenchanted with consumerism than Weber anticipated
152–65). Moreover, caging is a somewhat misleading and limited meta
an "exoskeleton," a cage that *serves* human beings—may be more appro
since the advance of science and technology also gives us greater powe
the environment, extending the human footprint.

Weber's notion of disenchantment pertains to modern or industr
ciety generally, and it specifies a pattern that accompanies all scientif
technological change within this type of society. Thus, there are alwa
sides to the advance of science and technology: on the one hand is the a
of instrumental rationality, or of seeking the most efficient means to a
a given end, which entails an increasing mastery over the natural and
worlds; on the other, this process also brings about the increasing imper
ity of the external conditions of life. The consequences of scientific an
nological advance are therefore not just economic ones; they apply to al
of social life.

This conception of science and technology enables us to identify th
tribution that specific advances in scientific knowledge and techno
artifacts make to the process of disenchantment since it allows us to sa
gains have been made in each case by instrumental rationality. The

scientific knowledge is separable from the world and that artifacts ar
objects, and it simultaneously takes into account the effect of this ac
the social world by means of Weber's concept of disenchantment.

The central concern of the sociology of science and technology
comes how we can translate the one into the other; that is, to tra
ways in which knowledge intervenes in the world and artifacts m
it—into the ways in which the external conditions of social life be
creasingly governed by how knowledge and technology are deploye
ever we encounter the science, technology, and society relationship
be able to identify both an advance in representing/intervening a
fining/manipulating that has taken place—and how social relations
changed in accordance with more powerful knowledge and more
artifacts.

This realist approach to science and technology applies to all lev
cial change—macro-, meso- and micro-. Once a distinction has be
between science and the rest of the social world, or between a sphe
nition whose validity is independent of social life (realism tells us
knowledge is separate from the world and that artifacts are physical
the significance of this separation is), then we can operationalize r
identifying the separate impact of this realm of knowledge and o
artifacts on society.

This is a good point at which to spell out the difference between
and pragmatist argument made here and the social shaping and co
ist approaches. What social shaping and social constructivism leave
what sets the position put forward here apart, is the coupling betwe
and technology and the physical or natural world. This coupling tr
society independently of social forces. This is illustrated in Figure
social shaping and constructivism recognize only the relationships
dotted line, whereas the position put forward focuses on the relatio
tween science and technology and the physical/natural world below
line (indicated by the arrow on the left), and thus recognizes the ind
impact of scientific and technological advance on social change (ind
the arrow on the right).

Note, first, that this latter position does not exclude the arrow
dotted line, but regards this relationship as secondary. Note, secon

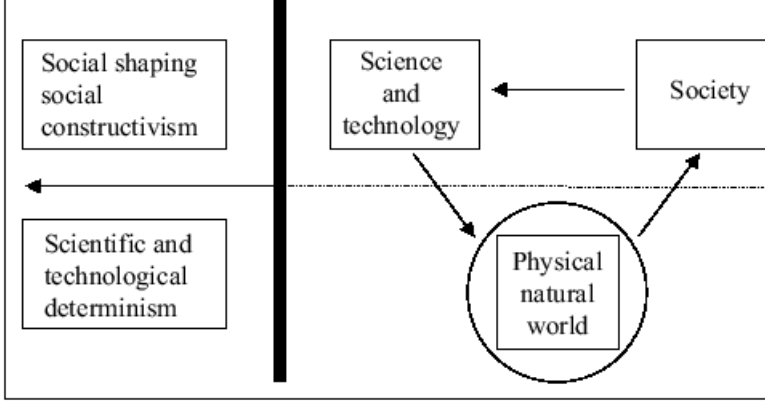

FIGURE 1.1 Figure Caption To Come

argue for this determinism only insofar as it can be yoked to specific processes (to avoid speculative determinism); in other words, insofar two arrows that cross the dotted line can be given a concrete content a ciological significance. Note finally that even if the arrow going from s and technology to society above the dotted line is seen as two-way (two-way process is often implied, but not spelled out, in social shapi constructivist theories), this still does not take into account the relation physical and natural worlds, as here. The realist and pragmatist positi forward here implies an epistemological conception of knower and w known as being separable, and of an analytical separation between the cal/natural worlds and the social worlds, even if there is an increasing locking between them in practice.

To this realist and pragmatist approach it will be necessary to add— it has already been alluded to and we will return to it later—that the r between science and technology has been variable. Until the mid-nine century, the two were not closely linked (Collins 1986: 113), but in th nineteenth century, high-consensus rapid-discovery science became lin technology. Cowan goes so far as to say that "in the twentieth century proved very hard to distinguish between technology and science. For m this century, technological development has been conducted using sc methods and scientific research has been conducted, and funded, for t logical reasons" (1997: 221). As mentioned earlier, this intertwining h

technology, which means in this context that we should see both p
of representing and intervening, refining and manipulating, and t
chantment and caging attendant upon these, all working increasing
dem. Therefore, although science and technology predate modern so
high-consensus rapid-discovery science led to the takeoff of econom
in the course of the Industrial Revolution, it is only possible to speal
gressive and systematic advance of science and technology and of di
ment affecting society *more widely* from the time of this link onwar

The further intertwining of science and technology in the twen
tury will be described further in Chapters 2 and 4. In Chapter 3 w
counter another feature of twentieth-century science and technolo
is that science has on a number of occasions become big science (Ga
Hevly 1992; Price 1986), as in the cases of particle physics or the h
nome project, while technological artifacts have become part of "la
nological systems" (Hughes 1987), as, for example, with electrific
telecommunications. In these cases, it is necessary to tackle simul
the wide-ranging social implications of science and technology o
hand, and how they have focused the attention of a large part of the
and development community and required a large-scale mobilizatio
resources on the other. This means, too, that in these cases, the exa
of the disenchanting consequences of scientific and technological
must encompass a wide range of simultaneous developments. An
need to remember that these labels only pertain to certain types of
and technological advance. Others, like smaller-scale laboratory re
stand-alone domestic technologies, will require different points of d

The relationship between science and technology and social life
ways a question of levels, and it is important to go beyond both a part
that is unable to arrive at any general patterns of social change (as
of individual areas of science and technology), as well as beyond ab
that does not apply to any concrete contexts: for different kinds of
and technological advances it is necessary to address different aspe
interrelationship between the two sides, but it is also necessary to see
between them. As we shall see, in the case of big science or large tech
systems, for example, it may be necessary to focus on the institut
mentum that has built up behind the research and development ef

which they are used. In any case, the later chapters in this book will id
several such patterns.

No doubt there are many different ways in which scientific and te
logical advances translate into everyday settings and it may be impos
determine, a priori, whether science and technology or social forces
shaping. What *is* clear from the outset, or what follows from the defi
given here, however, is that there will always be two sides to this interpl
side of an ongoing adventure (or advance, in my terminology) of repres
and intervening, or of refining and manipulating, and the side of disen
ment, or of an advance in instrumental efficacy and of the depersonali
of the external conditions of life—by means of greater control over an
mediation with the environment.

Beyond Social Shaping and Constructivism, and Some Puzzles Resolved

Before we go any further, some puzzles or seeming contradictions that
from my definitions can be anticipated. I will argue that one of the keys
derstanding the relationship between science, technology, and social
is to recognize that science is in crucial respects separate from socie
from culture. A common response to this idea is: How is it possible to
that science is separate from society? Isn't everything social, made by p
And don't all ideas or beliefs have to be part of culture?

This position only has to be put in a negative form—science and te
ogy can never be anything but social or culturally shaped or construct
recognize that there must be something wrong, too, with the idea that
must be social or cultural through and through. Science is indeed soci
it *must* also be independent of society since it clearly imposes constra
us—for example, when scientific laws are valid in relation to how they p
to the physical world, and thus regardless of whether society or culture
or constructs them so. (We will identify some other constraints later
similar way, science can indeed be regarded as part of our modern cultu
it must also be possible to separate science from culture since there is cl
difference between science and other things that social scientists want t
to as culture.

focusing on the notion of an "essential" difference between science
ture. One of the most interesting recent books in the sociology of sc
culture is titled *Against Essentialism: A Theory of Culture and Socie*
2001). It argues that the distinction between science on the one ha
culture and society on the other—is false. In this, the book shares m
recent constructivist ideas in the sociology of science and culture. Bu
Essentialism makes an *objectivist* case for this inseparability: Fuc
that it is possible to provide an objective social scientific account o
including science, in terms of its network structure. *Against Essent*
gues that science is not essentially different from other parts of cu
only in so far as its network is harder than other parts of culture.

Let us retrace this argument in his own words: Fuchs (elsewher
that science is cumulative: "what makes a science scientific . . . is it
strumental and experimental capacity for progress" (2002: 33), whic
argument here, but not for Fuchs—makes it unlike other areas of cu
Fuchs, the hardness of this part of culture can be explained as follow
nality prospers when the relevant world has been simplified and q
concentrating the attention space on a small and domesticated se
understood variables and parameters" (2001: 137). This seems like a
explanation of rationality, but it only takes a moment's reflection
stand why such a concentrated effort yields high-consensus rapid-
science, or blazes a trail of knowledge that is more universal than
philosophical, efforts that attempt to tame issues that cannot be so s
and quantified.

But let us follow Fuchs further: he goes on to argue, "what makes
'hard' and realist, rather than 'soft' and constructivist, is hardwar
other things" (2001: 306). "Realism," he says, "increases when a
grounded in routine machines, tools, and instruments, around the fo
technical cores of organizations. This effect is strengthened further a
terial means of culture are monopolized by an organizational hege
In laboratory sciences that occasion more copresence, encounters an
realism is anchored in the tangible reality of a here and now, with
cal interventions and manipulations" (2001: 330). Again, the termin
similarities to the definitions of science and technology presented ea
it can easily be seen that this is different from other nonrealist par

therefore misleading when he describes the realist part of networks in s
cal terms: copresence and anchoring in the tangible reality *here* and *no*
be required for the *local* production of scientific and technological ad
but what is unique about this part of culture is how easily it can be trans
to other places, and thus how context independent it is.

My argument, against Fuchs, is that this difference entails that scien
the other parts of culture are not just two parts of the same animal
speak, but that they are different animals altogether—an essential diffe
I would argue that analytically, but also from the point of the view of t
dence, there are only two options: one is to separate science from cultu
gether, and the other is to subsume science under the rubric of culture,
say that in this case science consists of an essentially different part of cu
These two options are represented in Figure 1.2, where the triangular

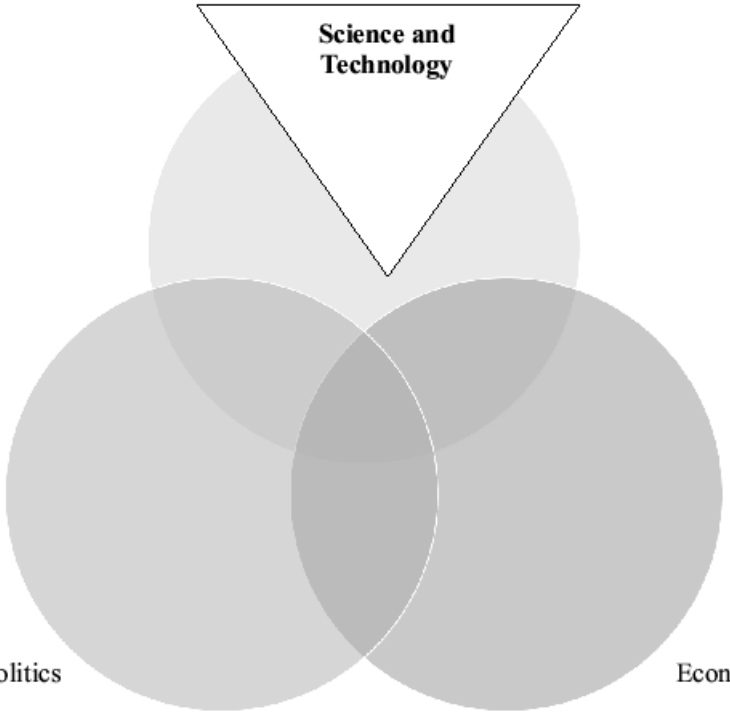

FIGURE 1.2 Figure Caption

e comma "spheres"?

separate from the circle of culture in the first place. (Sociological an far less trouble, if any, with the separability of the other two sphere tics and economics.)

We will come back to this repeatedly, but the issue cannot, of c resolved in the end merely on a conceptual level. I will have to sh in practice or by reference to substantive social changes, the extent science/technology *translate* into cultural (or into political and e change, having been separable from it—or vice versa. Be that as i now, in what follows I shall agree with Fuchs that this hardness of sc technology, as opposed to other parts of culture, needs explaining.

There is a related puzzle: Ideally, we should be able to treat knowledge as a belief system. If science is "our" belief system—or c ideology—then one approach has been to argue, as Gellner does, th liefs should be translatable into another language (1979). So, for exa gion can be translated into economic benefits: salvation payoffs, pren deferred gratification, and the like. A related approach, proposed b (and which will be pursued below), is to treat scientific truth or know "sacred object of the scientific cult" (1993: 302), with rituals desig inforce this deity: common worship of truth, status deference in th the scientific priesthood, and so forth. The reason for mentioning arguments is to notice their limitations. As Gellner and Collins n treating science as a belief system can only ever partly work for sc cause science also locks onto the world and thus changes the worl that other belief systems do not (Collins 1975: 520; Gellner 1988: 70 differently, our belief system *can* be explained in this way, as ideol

mmas in sentence?

culture, or as the worldview that dominates our society. Yet the so significance of science does not lie primarily in the fact that it can be belief system like others, but in what scientific knowledge *does* as a u lief system, and this, again, is to transform the world, part of which, a see, is to eliminate other belief systems or all-encompassing worldvi

Something similar applies to technology. The sociology of techno also other social science conceptions of technology, have been un some notable exceptions that we will return to—to make up the whether technology must consist of material artifacts: Should techn restricted to hardware, to machines? No, it is typically argued, te

apart from artifacts (this is often argued in the economics of innovatio
the like. Again, I will depart from this consensus in arguing that tech
must at a minimum include a material component, and that the sociolo
significant component of technology apart from its artifactual nature
part of the environment that has been transformed by this technology.

The Extension of the Human Footprint

A different way to clarify the separability of science and technology
culture and society is to pursue the puzzle that science and technolo
produced by human beings: how, it can be asked, is it possible for scien
technology to be outside of a social context if science and technology a
viously human products and therefore inevitably social? But to para
Marx, we may make science and technology, but we cannot do so as we
Science also constrains us, as when the evidence compels the vali
knowledge, and technology constrains and enables our relation to th
ronment around us (and vice versa).

Another argument can be brought to bear, not from the side of co
or theory, but from the side of the evidence. If scientific and techno
determinism is true only in relation to its social context, the social c
is literally universal in the following way: elaborating on the term bor
from environmentalism earlier, which talks, in the context of sustain
about the human footprint in the environment, we can use this conce
broader sense, to indicate the transformation of the environment by s
and technology (the connection with the definitions of science and te
ogy in terms of disenchantment and the notions of caging and a huma
skeleton will be obvious here). If so, it can be recognized immediately th
human footprint has grown ever larger, reaching a historically unprece
level of growth in the twentieth century that has encompassed the globe
beyond. As McNeill puts it, "the human race, without intending anyth
the sort, has undertaken a giant uncontrolled experiment on the ear
Although there are a few kinds of environmental change that are new
twentieth century . . . for the most part the ecological peculiarity of the
tieth century is a matter of scale and intensity . . . matters that for mil
were local concerns became global" (2000: 4).

human habitation, and thus of society: it has extended into realms
small that lie outside of social relationships, only interlocked by kno
by machines (for example, by instruments of measurement or obs
Among the examples that come to mind are ocean depths and galax
macrolevel and subatomic particles and genetic material on the mi
To the objection that the human footprint must be social because it
by humans, it can therefore be replied that not all the extensions
activity are within the compass of social science, and this especially
(physical and extrahuman) phenomena covered—or interlocked—b
and technology and their instruments. Thus the impact of science
nology, insofar as the human footprint extends beyond society in a
ingful sense, is literally universal.

Again, the same seeming contradiction crops up in relation to te
the argument made here is typically countered with: there is no s
as technology without humans, or technology outside a social cont
argue against this too, though it is necessary to make an analytica
tion that is somewhat different from the case of science. What lies
science is the physical world or nature, the reality in which science
and intervenes; what lies outside technology is the physical enviro
which humans are subject, and which in this context is nothing a
how this environment undergoes an ongoing refinement and mar
by artifacts. (Refinement, incidentally, might be taken to imply ma
ter. I use *refining,* like *advance,* in a value neutral way: a cage can be
by making it more constraining, just as it is possible to "advance" t
Armageddon.) In short, science and technology, though analytically
are never separate in practice from what they *do* to the (physical o
world, and this is also the key to resolving the seeming contradic
have just been mentioned and advancing beyond the mistaken
outside-of-the-social-context view.

Proponents of social shaping, and even more so constructivists
blur the distinction between science and nature, or between cultur
ture, and partly for this reason they cannot identify the sense in wh
tific knowledge grows and changes the natural or physical world.
with technology which, if it is only culture, only changes our beliefs
rather than the external environment. A-social scientific realists, on

e comma
efore
ich"?
,
te comma
"ideas"?

Instead, they dwell on truth in the realm of abstract ideas—the inter
that social shaping rightly criticized. And similarly for a-social techn
cal determinists who claim that technology changes everything, which
that technology does not actually change any concrete social relation
again, in view of the premises of my argument that it is essential to sho
knowledge and artifacts *do,* and not just assert their universality in t
stract—the autonomy from the social context, and diffusion throughou
ous social contexts, will need to be demonstrated *in practice* in what fo

To get beyond these abstractions, we need to take the evidence int
sideration, since all our concepts are bound or bounded by evidence. T
evidence we have for how the relation between science, technology, an
ety has changed comes from comparative history and substantive socio
findings, and it is to these that we can now turn.

Before we do so, a brief map of the book is called for. Chapter 2 exa
the institutional bases of scientific and technological advance; how are
tific disciplines and technological artifacts organized to move forward r
This process has so far mainly been described for individual cases, but l
attempt is made to cover how these institutions are organized to foster a
along a cumulative frontier and how they draw on resources from socie
establish their legitimacy. In Chapter 3, we will move on to the main m
tations of these institutions in the twentieth century, big science and larg
nological systems. These two large-scale institutions have become phen
that reach out beyond science and technology and affect society at larg
dependence on these two institutions has become taken for granted, b
only became possible in a society in which economic growth had for t
time become a permanent and routine feature. The coupling of techn
and mass production changed the scale and scope of consumption, an
a steady stream of innovations are turned into mass consumer goods ha
much discussed in economic history. In Chapter 4 this process is des
from a longer-term historical perspective: what are the main stages in
this process became institutionalized on a large scale, and when and how
become widespread throughout the developed world?

The study of how innovation is driven (or not) by demand in today's
omy on the production side has been much debated. The *uses* of tec
gies, on the other hand, have been relatively neglected. Chapter 5, th

The cumulative and systematic impact of technologies in relation t
has often been overlooked in relation to political change, as has the
national systems have in an important sense converged. Similarly
consumption of technologies changes everyday life, a topic that has
extensively studied, and hardly at all from a long-term and compar
spective. Chapter 6 therefore examines three such technologies in d
telephone, and television. These, it is argued, have changed our ever
in the direction of a more homogeneously diversified lifestyle and cu
conclusion argues, finally, that these substantive ideas about science
ogy, and social change add up to a new theoretical agenda that goe
social shaping and constructivism and a crude or speculative determ
spells out the implications of this agenda, the extent and limitation
it has been worked out in this book, and the consequences for wide
about how science and technology change society.