2. Many visible hands

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INTRODUCTION

Compared with the ‘careless technology’ of the 1960s (to quote the title of a book at the time (Farvar and Milton, 1972)), the present safety, reliability and environmental friendliness of many products and technologies, at least in the richer countries, is striking. Salmon are swimming in the Thames again. Companies like The Body Shop, but also 3M and Proctor & Gamble, pride themselves on their contributions to sustainability, and are recognized for it. Critics might call these accomplishments ‘rearranging the deckchairs on the Titanic’, and point out ongoing exploitation of natural resources, the hazards of the man-made environment, and long-term macro-risks such as climate change. For the moment, our interest is not in who is right and who is wrong, but in the observable fact of an overall change in the last decades, as well as the widespread recognition of the importance of paying attention to environmental aspects. In addition, in contrast to blaming the technology of the 1960s and 1970s as perhaps inherently ‘careless’, many stakeholders in these issues are interested in new technological options. They actively seek technological development (or better, socio-technical developments) to contribute to solutions of environmental problems, including the uncertain but possibly staggering climate change problem.

A double question can now be raised: how did improvements which are clearly in the public interest emerge at all, and can one expect further changes now that demand for climate-friendly technology appears to be articulated? Clearly, there must have been more to the overall changes than the market mechanism – these would not automatically lead to public-interest developments anyway. Hierarchy (cf. Williamson, 1975, 1985), where governments set rules and create structures to realize public interest, has its own problems of information deficits and limited compliance. The now fashionable ‘third way’ of networks (of various kinds) is important, empirically (there are such phenomena and they are productive) and theoretically (especially because it forces economists to add some sociology to their approaches). We locate our approach as primarily a network approach, but with some twists. For one

thing, we see market, hierarchy, and networks as subsets of general action patterns and how various (emerging and stabilized) institutions enable and constrain further action. For another, we think technology is part of such processes, not an exogenous factor impinging on actors and institutions. One way to emphasize this point is to speak of co-evolution of technology and society, and the attendant co-production of outcomes (Rip and Kemp, 1998). The limited malleability of socio-technological development then becomes a challenge as well as an opportunity.¹

The central question of this chapter can now be formulated as follows: how can heterogeneous processes of socio-technological development lead to outcomes which are (more or less) in the public interest, and can we derive steering possibilities from insight in the dynamics of such processes? In particular, how can such developments ‘work’ if we accept that there is no invisible hand guiding the overall developments, nor an overarching benevolent ‘visible hand’ of government (or any other authoritative actor), which can be held responsible?² Phrased in this way, it is clear that we are inquiring into *de facto* governance modes, which have emerged without there necessarily being actors working towards them intentionally. Eventual intentional steering will have to take such dynamics, and their limited malleability, into account.

While our question derives from empirical observations, we shall not mobilize data and analysis in search of an answer. Rather, we will try and create an overall perspective. To do so, we use overlapping theories and approaches, starting with stakeholder theory of the firm (Mitchell *et al.*, 1997) and so-called quasi-evolutionary theory of technological change (Van den Belt and Rip, 1987; Rip, 1993). Focal organizations interact with actors in their environment, and this can be seen as an attempt to influence their selection environment. Such interactions get ‘aligned’ and build up to patterns and structures (including ‘regimes’ orientating technological development), which become relatively independent of the original interactions and will shape subsequent interaction – small invisible hands, as it were. This is a general sociological phenomenon, and one which has been addressed in a variety of ways: the dynamic version of Coleman (1990)’s boat, in Van de Poel (1998); actor-centred institutionalism (Scharpf 1997, Schmidt and Werle 1998, also Weyer *et al.* 1997), Callon’s (1992, 1995) work on ‘regimes of translation’, and some work in neo-institutional sociology, for example Hoffman (1999).

This body of theory (which is reasonably coherent in spite of the different underlying ontologies) implies those meso- and macro-level patterns, their changes and their effect are important. We have to avoid the pitfalls of black-boxing the world, and the assumption of classical economics that it is atomistic, or can be treated as such (see Granovetter, 1985). Also, social science theories that have looked at stability and change from a systems perspective can

now be mobilized. In particular, Groen (1994) has shown that basic elements of Talcott Parsons' work can be used to understand interactions in innovation processes (in his empirical case, of SMEs' adoption of environmental technologies). These theoretical approaches have been seen as contrasting, and perhaps incompatible. While there are differences, there are also subterranean connections. In particular, a surface difference results from the focus of some theories on explaining 'cold', stabilized situations and patterns, while others delight in exploring 'warm', fluid situations and patterns (the 'cold' and 'warm' metaphor is borrowed from Callon (1998), while the contrast between 'fluid' and 'specific' derives from Abernathy and Utterback, and was developed by Garud (1994). In other words, the different theories can be combined in a dynamic multi-level perspective; while this idea informs our analysis, we shall not develop it systematically in this chapter.

In this brief sketch, two levels can be recognized: how myopic actors get shifted out of their way, and how agendas, regimes and structures emerge behind the back of actors and do their work. There is a third level as well, of socio-technical change on a larger scale and over longer periods. We shall discuss processes and outcomes at these three levels in separate sections, not as a sustained argument but as an attempt to present a composite picture. Almost as a triptych in a medieval church the three panels tell their own story, but together they create the overall thrust.

THE FIRST PANEL OF THE TRIPTYCH: FROM FOCAL ORGANIZATIONS TO NETWORKS OF INTERACTION

Let us start by considering a focal organization (or more generally, a focal actor) and introduce external actors, using the analytic versions of stakeholder theory of the firm (cf. Mitchell *et al.* 1997) as a starting point. Since we are not interested in theory of the firm as such, we can entertain a larger variety of relevant actors. Among the stakeholders, particularly relevant to our question are the actors linked to the focal organization in industrial networks (Håkansson and Snehota, 1995), and the indirectly relevant or second-order stakeholders like insurance companies, activist shareholders, regulatory and promotional government agencies. Then there are the so-called new stakeholders: potential and actual users, environmental and consumer groups, self-appointed 'influencers', early warners. Depending upon one's position, one may include some or all of them among the stakeholders, that is, accept them as actors who really count and should count, or treat them as actors out there whom one encounters. The distinction affects the choices and actions of the focal organization. Since the focal organization employs itself and other actors in this way, this will influence how others will react; together, this will

shape process and outcomes to some extent. Think for example of how the Royal Dutch/Shell Company responded to the first criticisms about its Brent Spar decision, and how it was forced, in the end, to renege on its decision (Rip and Talma, 1998).

External actors (however viewed by the focal organization) have their own position and interests, and will try to enrol the firm for their purposes. Mutual translation (as actor–network theory phrases it) occurs, actors on both sides of a relationship influence each other. For our question about how the public interest might be served, it is important to note that ‘actors’ may well include evaluators, mediators and CTA agents (Schot and Rip, 1997).³

While every actor will position itself as a focal organization (the term ‘organization’ now includes the case of just one individual in a public role, cf. our earlier remark on focal actor), the overall development will have no pre-given focus. Of course, there are all sorts of asymmetries, and some actors may think themselves to be sufficiently powerful to act and shape the world from their point of view (and if they enrol the right allies, they can go some way in this direction). Industrial network theory has emphasized such a symmetrical approach, where external actors and focal organizations are endogenized as elements of one network (Håkansson and Snehota, 1995). This approach is important when tracing concrete interactions and dependencies, but has not yet included (because of its focus on production?) public interest actors and credibility pressures, which appear to be important for our question. A further step is done in actor–network theory when criss-crossing mutual translations are taken as the basic phenomenon. Actors themselves are then endogenized as residing in the networks that result from the mutual translations. In other words, one can take the interactions as the basic elements, and see actors as temporary assemblages of interactions. Problematizing actors and their boundaries is important for further analysis (and especially if technology is included in the interactions and patterns), but for the moment it is sufficient to note the possibility. In any event, focal actors will remain important because actors see themselves in this way and understand and shape their actions on this basis. Our argument up till now can then be phrased as implying that a focal organization has to take a broader view or run the risk of ‘short-termism’. Actually, they recognize such a message, at least in public declarations. How does it work out in practice?

Firms and the Broadening of Networks in Technology Development

At the micro-level of firms, and of technology ‘introducers’ more generally, one sees, by now, a great deal of defensive anticipation. This often remains short-termist through selective use of signals and selective involvement of actors. Interaction with other actors is one way to broaden one’s horizon, but

may well lead to closed shop interactions. For that reason, a focal organization might welcome (some) contestation. In the biotechnology sector, actual or potential contestation has now forced firms (whether they wanted to or not) to interact with spokespersons of relevant groups at an early stage (Deuten, Rip and Jelsma, 1997).

Short-termism, however, is part of the *condition humaine* (or *condition d'entreprise*), an unavoidable component of the need to act in the here and now. Even when trying to overcome short-termism, it is impossible to be comprehensive, especially with novel technologies and unknown markets. This is not just a matter of uncertainties that are gradually reduced when experience accumulates. Interaction between parties positioning themselves and others leads to specific dynamics which can steer (that is, constrain and enable) the development.

A new product (or new technology) can, for example, split the market when proponents and opponents define themselves – sometimes to the surprise of the insiders.⁴ In the example of genetically modified food, the market is also split, but there is a spectrum of market and stakeholders reactions. The UK has a dichotomy between the ‘realists’ and those who are concerned about ‘Frankenstein food’ (including Prince Charles, who opened a website to allow concerns to be voiced). Key actors like supermarket chains shift their position (toward labelling of GM ingredients) and thus add momentum to the critical movement. Other countries appear to accept the new functionalities wholeheartedly (USA) or limit criticism to genetic modification of animals (the Netherlands). The processes in play here can be understood as the interaction between promise-requirement cycles and threat (risk)-requirement cycles (Van Lente and Rip, 1998; Rip and Talma, 1998). Recent changes in GM food acceptance and regulation show that positions are shifting again – in other words, market segmentations are outcomes of processes and cannot be specified independent of them.

Are we seeing, in these examples, cases of conservative users, who refuse to change their ways, or of insensitive developers? Both, or better, neither. We see the problem of a public interest not being definable in an unambiguous way. Categories like ‘conservative’ or ‘insensitive’ are retrospective, and can be applied only with the benefit of hindsight, when outcomes have stabilized. In fluid, not yet articulated situations, such labels are attempts to position oneself and the other, leading to mutual translations and eventual stabilization. There is no way to adjudicate between the positions of promoters and critics at an early stage of development.

In addition, there is a methodological challenge. When a new product is introduced, and before that, when it is developed, there is no direct way to test what the outcome will be, in spite of all the sophisticated methods of market testing and scenario building. There is no principal problem of simu-

lation of a future situation. The involvement of actors takes place in an artificial situation, and outcomes are not a predictor of what will happen in the 'real' world when the product is actually introduced. In general, first-round tests (to reduce the risk of non-uptake of the product) have a conservative bias because usage and acceptability will articulate further after introduction (Hoogma and Schot, 2000; cf. also Bower and Christensen, 1995). Incidental checks of the environment, including interaction with potential users, have to evolve into continuous learning and feedback. A case in point, which is already at an early stage of product development, is how market prospects and patent situations are checked to decide whether to invest in the development of the product. These are then taken up again only when prototypes are available and market introduction is planned – by that time the world has moved on (Rip and Schot, 1999).

Marketeers and other analysts emphasize, in various ways, the importance of 'probing and learning' (Lynn, Morone and Paulson, 1996), and distinguish strategies like 'Darwinian selection', 'product morphing' and 'vicarious experiments' (Leonard-Barton, 1995). This in addition to structures like government-required testing and licensing of new products, such as medical drugs, which attempt to protect society from the risks of short-termism. To work with innovative users instead is sometimes done (Cooper, 2000), but runs the risk of drawing on a segment which cannot be a predictor for articulation processes of the majority of users.

Interaction with users and stakeholders is an addition to the arsenal of methods, but by itself is no guarantee of success. The interesting phenomenon about learning strategies and interaction with user and other stakeholders, however, is that it is not an *ad hoc* problem-solving tactic any more. A new practice is emerging in which anticipation on wider issues and interaction with more actors is becoming accepted, even expected. In terms of quasi-evolutionary theory of technological development, this is an example of a 'nexus' between technological developments and societal selection environments: an institutionalized link that will structure their co-evolution. (Van den Belt and Rip (1987) discuss test labs as an example of a nexus, while Fonk (1994) studies interactions with consumer groups as an emerging nexus.)

New Practices of Anticipation in Environmental Strategies of Firms

The driving force for the emergence of new practices in the case of sustainable technologies and products is a combination of prudence and strategic positioning, rather than public interest considerations *per se*. This is brought out emphatically in Hart's (1995) analysis of new capabilities of firms with regard to environmental challenges, and the various interactions with the (selection) environment that goes with them. He suggests three stages (of

capabilities, labelled with suggestive names), with increasing scope of activities and anticipations, each with its own version of competitive advantage. What is competitive advantage to the firm, and/or to the manager who will be evaluated, is at the same time in the public interest, because Hart assumes regulatory and credibility pressures in this direction.⁵

Table 2.1 summarizes Hart's own analysis. Hart's analysis can be re-interpreted as indicating the possible scope (here, occasioned by environmental and sustainability considerations, but the argument is more general) of a firm's actions and interactions, and the attendant complexity of its relevant selection environments.

Table 2.1 Environmental strategies according to Hart (1995)

Capability	External pressure	How to do it	Competitive advantage
Pollution prevention	Minimize emissions, waste	Continuous improvement	Lower costs
Product stewardship	Minimize life-cycle costs of products	Early integration with stakeholders	Pre-emption of competitors
Sustainable development	Minimize environmental burden of firm's growth and development	Shared vision	Future position

From the point of view of the focal organization, the environment becomes more complex and more uncertain, and the organization will initiate further actions, as exemplified in Hart's scheme, to meet this challenge. The fact that a broader scope is addressed (out of necessity) has implications for the firm's actions, which may well contribute to a public interest eventually, and for its interactions – it cannot go back to earlier, more limited approaches without losing credibility. What started out as specific action and interaction cannot always be turned back without costs. In this way, irreversibilities typical for path dependency arise in individual cases. But it is not just a matter of individual cases: expectations are stimulated more generally, and firms (focal actors) have to do something to meet them. The practices labelled by the slogan 'pollution prevention' now function as an institutionalized nexus. The 'Sustainable Care' programme of the chemical industry world-wide in the 1990s has also created sustained interest in product stewardship, which appears to be an emerging nexus. Under the slogan 'sustainable development'

there is no identifiable nexus yet, but one can speculate about possibilities (and then work towards them intentionally). The three actual or potential nexuses are of increasing scope in terms of number and variety of actors, time horizon and geographical spread. Figure 2.1 visualizes this idea; even if the suggestion of two independent axes is misleading: larger temporal and spatial scope may well go together with increasing numbers of actors.

Figure 2.1 Increasing scope of a firm's actions and interactions

Because Hart limits himself to competitive-advantage arguments, that is, decisions to engage in a certain process or product development, he neglects the substance of the interactions. When a novel and untried technology (artifact, system) is to be introduced in a (selection) environment, alliances with stakeholders are important, but not only to pre-empt competitors. They allow real-life, joint learning, as we noted before. In addition, one now sees various mixes of joint public-private efforts, most often at the initiative of public actors. Initiatives are set up, and private actors participate in them, not for immediate gain but because of the symbolic value of working (and being seen to work) towards sustainability. This allows us to make a further point: actors to mobilize others and/or to position themselves as credible can invoke the reference to sustainability as something important in our society. 'Sustainability' itself, as a slogan, becomes an ally, and contributes to the success of experiments.

Conclusion of the First Panel

There is a general trend to entertain broader horizons and to include more actors. For the focal organization it is a way to meet uncertainties and to act prudently in dynamic environments; for other actors it is an opportunity to translate focal organizations. This could also be approached from the perspective of stakeholder analysis, but with the stakeholder as focal organization – and the phenomenon of courses training environmental groups how to harass private firms and public authorities then falls into place. It is through the mutual translations that occur that immediate self-interest of actors is transcended (on all sides of the fence), and a measure of sustainability may be achieved. But always precariously: since goals like sustainability remain diffuse, and have to be so to enable alliances. Without further institutionalization, such goals will not be very directive, and actors will not remain aligned sufficiently long to allow lasting results to be achieved. This is even the case when government authority is added to shift the balance, as happens in technology-forcing regulation – the implementation of the USA Clean Air Act for emissions of motor cars is a well-known example (Schot and Rip, 1997).

The present hopes for more user involvement should be positioned in this dynamic force-field as well, as users introduce their own type of short-termism. This is not a message of despair: there are all sorts of advantages, but no assurance that this will be the royal road to better technology in society. What does happen – and this has already been brought up in a number of times in passing – is that actions and interactions of somewhat enlightened self-interested actors introduce couplings, dependencies and anticipations, and not just in industrial networks, but also in forceful repertoires. This is how we discussed the notion of ‘sustainability’ as being not forceful by itself but, when part of a more or less institutionalized repertoire, a rhetorical device. Rip and Talma (1998) have made a similar point about the emergence of risk repertoires. Gradients are introduced which limit the movement of the various actors. Such gradients are more important for overall outcomes than correct attitudes or mindsets.

While forceful repertoires, together with other institutions, definitely put constraints on the immediate negative effects of short-termism, there is no guarantee. The overall structure of the evolving arrangements, what we called *de facto* governance in the introduction, is one element to consider here. But also the ongoing development of novel technological options, of ‘variation’ as evolutionary theories would say. Given the uncertainties involved, to work for a ‘leap’ toward possibly sustainable technology requires the faith of the dedicated entrepreneur.⁶

THE SECOND PANEL OF THE TRIPTYCH: EMERGING STRUCTURES AND INSTITUTIONS

We can now position the short-termism of actors, and how it is mitigated, differently: not as a particular behaviour and perspective of actors, but as an effect of emerging structures and regimes 'behind' the actors. Even in the active version of short-termism, where the actor tries to set the developments to its hand by changing or managing the selection environment in such a way that its present or potential innovation will have a better chance of survival, this is the case. Such strategic action is actually one of the routes to new structures and institutions, and one that is neither completely predictable, nor completely manageable for the active actor. Negotiations about industry standards, in telecommunications as well as in other domains, are a well-known example (Schmidt and Werle, 1998).

Patterns and structures emerge, which enable productive action and interaction, but within their own terms. In that sense, they also act as constraints. For actor strategies, and for analysts who reflect on the pattern and present their analysis to actors, there are two sides to this. If you want something other than what is now enabled, you will have a hard time; but if you can get 'your' aims incorporated in a newly emerging pattern, it is not necessary to work for them any more, the pattern will do that for you (Rip and Schot, 1999). That is exactly why it is so important for firms and other actors that the 'right' industrial standard emerges.

Recognizing the importance of the standard does not imply that actors understand the dynamics and are able to get their way. This further example of the *condition d'entreprise* is even more pronounced in the case of less concrete institutions like the different examples of nexuses discussed in the first panel, and for emerging socio-technical regimes (Rip and Kemp, 1998; Dolfsma *et al.*, 1999). Unintended and often-unexpected effects occur because actors do not take the overall dynamics into account. However, while actors might be exhorted to include possible wider changes, this can never be done comprehensively because of bounds on information, time and effort, and the unpredictability of emerging structures.

Network structures, culturally accepted patterns and regimes, and strategic games enable and constrain like small invisible hands, but without much pretence at optimizing.⁷ Analysts (and reflexive actors) can make the work of these invisible hands visible. Will that help to realize public interest? Often, it just allows the actors to play their games better.

The broad-brush diagnosis we offer here is actually a general social-theoretical point, and one that has been addressed, in various ways, by almost all social theories. We will make a brief *tour d'horizon* of relevant theories and

theoretical approaches, adding some recent developments, and evaluate what we can learn from them.

Evolutionary Perspective on Structures and Institutions

Short-termism can be seen as a component of Darwinian evolution: variations are blind with respect to the selection environment, and contingent survival is the mechanism (cf. the first of the marketing strategies discussed by Leonard-Barton, 1995). A quasi-evolutionary approach, or better, a non-Darwinian evolutionary approach that includes anticipations of actors, is necessary. Such an evolutionary approach helps to understand outcomes of innovative ventures, and offers us also a gloss on actor strategies. It does assume a relatively independent actor who sees the world in evolutionary terms and shapes his actions accordingly. This is the approach taken in evolutionary economics (in general, and in the analysis of technology and firms). A sociological component should be added, however, or made explicit in the more enlightened theories of the economists (cf. Van den Belt and Rip, 1987).

Emergent and stabilized structures and institutions are not just out there. They are, however, there to exploit as one sees fit. They enable and constrain action in a variety of ways, for example in terms of problem definitions shaped by prevailing paradigms, dominant designs, and 'natural trajectories' (Nelson and Winter, 1982) like mechanization and modularization. The notion of 'capital', accumulated in earlier action but then in terms of what the regime (or structure, or institution) emphasizes, is another way to capture the duality of actors and structures. It has been used by authors with different theoretical backgrounds, ranging from Latour and Woolgar (1979) on science, and Bourdieu (for example, Bourdieu and Passeron, 1977) on cultural capital, to elaboration of Talcott Parson's approach by Groen (1994) and Groen and Nooteboom (1998) on four types of capital (political, economic, cultural and social). This literature has focused on explanation of behaviour and strategies of actors using an explicit or implicit sociological structural approach. It can be elaborated further to address the question of emerging structures, as is evident in the notion of foregrounding in Callon (1998) and 'prospective structures' in Van Lente and Rip (1998). The latter especially highlight the importance of expectation and their stabilization into repertoires and story lines, which implies that other kinds of theories become important as well. We shall briefly discuss both kinds of theories, in an effort to show the need to entertain a broader concept of structure than in traditional social-structural theories.

Towards Structural Description of Small Invisible Hands

There is a series of overlapping theories which address the question of emerging patterns and structures, often sharing our entrance point of focal organization, its interactions, and the overall set of actors and interactions of which they are part. Theories such as stakeholder theory (cf. Mitchell *et al.* 1997), evolutionary theory (Nelson and Winter, 1982; Stoelhorst, 1997), quasi-evolutionary theory (cf. Van den Belt and Rip, 1987; Rip, 1993), actor-network theory (Callon, 1998; Latour, 1987; Law and Hassard, 1999), industrial network theory (cf. Håkansson and Snehota, 1995), network theory (Burt, 1982; 1992), social system theory (Parsons, 1951; 1977; Groen, 1994; 2000), and Coleman's (1990) attempt at synthesis (even if based on methodological individualism) are examples of such theories. The patterns and dynamics they discuss are the same, even if the explanatory mechanisms offered need not be the same. What is important for our argument is that they share the recognition of effects at the collective level, as *effets pervers* because unintended – but not necessarily negative. In fact, the changes in technology and society toward sustainability which we took as our entrance point should be explained as such *effets pervers*; in this case, welcome ones. While the range of theories just outlined all depict structures (of various kinds) as enabling and constraining, they have little to say about the direction of the ensuing development.

Many of these theories focus on 'production', and interactions have to do with delivering, with mutual dependencies because one could not deliver (and survive) without the other. Structural influences can be analysed by network analysis providing a picture of positions of actors in a field of technological development. Following social system theory, relational analysis can be guided by three other mechanisms. A technological regime is an example of a pattern maintenance mechanism. In the economic domain, differences in efficiency explain differences in success of actors exploiting new technology. In strategic analysis a game of power play may become visible which in its turn is influenced by structural differences in power in the starting situation, but develops in interaction based on results of this interaction (possibly influenced by new actors).

As we have seen in our analysis in the first panel, there is more to say, however. For example, credibility pressures work on the symbolic level, but are very real. This point can be articulated further by introducing the second cluster of theories, many of which focus on the public domain: policy network analysis (Mayntz, 1993), sub-politics (Beek, 1992), discourse coalitions (Sabatier, 1987; also Hoffman 1999). While they study interactions and interdependencies, their focus is on content, on discourse, on agenda building. As long as they limit themselves to the study of political decision making,

with focal organizations like government authorities who are, or want to be, centres of calculation and optimization to fulfil their political mandate and responsibility, this limitation is relatively innocent. But it is a limitation: policy networks and discourse coalitions are also linked to production networks, directly and indirectly, and it is a challenge to theory (and to empirical studies) to address the combination.

Assuming for the moment that such an integrated theory is available, we can position the second cluster of theories as showing up a limitation in the first cluster, viz. the neglect of discourse and storylines (actor–network theory is the exception, although it has not really succeeded in integrating the two sides of the theoretical coin). How can this be brought in? At the micro-level, this is possible, as is evident in the new interest of management studies in narrative (Czarniawska, 1997), and the interesting example of *effets pervers* through narrative dynamics provided in Dueten and Rip (2000). At the meso- and macro-level, there are fewer examples, but we can indicate fruitful directions.

Our entrance point here is the recognition that regimes, structures and technological or innovation communities, when stabilized – say because their discourse coalition has become dominant – are protected by a mandate or charter. Marvin's (1988) analysis of the emerging profession of electrical engineers in the late 19th century is an interesting example. The notion of a mandate or a charter is like a constitution: a combination of authoritative rules and societal legitimation and justification, but now for specific domains, professions and institutions. And while parts of it may be written up after the fact, it is an emerging, *de facto* constitution.

We extend this approach further by recognizing other types of enabling and constraining legitimations in our society. 'Product stewardship' and 'sustainability', as discussed in the first panel, would be examples. Elsewhere, we have introduced the concept of ideograph to capture the function of ideological, but open terms like 'progress of science', 'industry' and also 'sustainability' in the rhetorics as well as the practices of science and technology policy (Rip, 1997; cf. also Van Lente, 1993). To indicate that a term works as an ideograph, we can write it in capital letters. Thus, in the case of experiments with electric vehicles, one can see how *sustainability* functions as an abstract sponsor: actors can refer to it for legitimation, and use it to exert pressure on other actors (Hoogma, 2000). While each concrete attempt at (mutual) translation with the help of *sustainability* may fail, there are a sufficient number of successes, and each success increases the ideographical force of *sustainability*.

Conclusions of the Second Panel

Instead of actors and their interactions, we have looked at the more or less continuing patterns in these interactions. These take various forms: strategic games, technological regimes, sector structures, markets, institutions in general. Actors and their intentions are backgrounds, and public interest outcomes like sustainable technology become effects – positive perversities – of such structures and systems and their co-evolution. While one can study specific patterns and trace such effects, the important additional point is that the small invisible hands are dependent. The way they link up creates arrangements of small invisible hands, a mosaic which it constrains and enables, indirectly. This is how society works.

The question can then be raised about the quality of the arrangement. Some mosaics are better than others – if we only knew which, and why. The way a mosaic is arranged is a *de facto* constitution (when seen in terms of legitimation), and a *de facto* mode of governance (because it structures and orientates the dynamics). Such arrangements emerge and stabilize – almost inevitably so, as a socio-political version of the path dependencies traced by economists and sociologists of technology (David, 1985; North, 1990). And one can ask if some paths are better than others.

Such questions have been discussed in political theory, although the focus there has been on the nature and functioning of arrangements that were stipulated and/or laid down in an explicit constitution, rather than on emerging *de facto* constitutions and the nature of the path toward them. Such dynamics are particularly important when technology, and the introduction of novel options, are included in the picture. While there is increasing interest in socio-technical instead of just social dynamics, and there is discussion of a constitution for a technological society, and of technological citizenship (Beck, 1992 is just one example), the analysis is often hampered by an outsider's view of technology and its embedment in society. Therefore, we will consider, in the third panel of the triptych, how we can draw a better picture.

THE THIRD PANEL OF THE TRIPTYCH: TECHNOLOGY AT DIFFERENT LEVELS

What the preceding section shows is that there are meso-level phenomena with their own dynamics, phenomena which actors have to take into account in order to survive and prosper. Sector-level watchers can contribute, and have been doing so informally for ages, making the small invisible hands visible. What is increasingly important is to include the meso- (and macro-) dynamics of technological developments and socio-technical interactions and patterns.

(Also, technology scholars can take up the role of making these invisible or only partially visible hands visible – as we are doing in this chapter).

In traditional analyses based on markets, but also on market-line selection environments, there is insufficient attention to technology. Take the example of GreenFreeze, the fridge using inert gases instead of chlorofluoro carbons which damage the ozone layer: the possibility of such cooling systems met with hand-waving refusals by the major manufacturers, until Greenpeace allied itself with a small manufacturer and developed an ozone-layer friendly fridge. A domino effect ensued, and all manufacturers started producing such fridges.⁸

Realizing sustainable technology can be seen as a matter of actor's intentions (not very reliable, but if they are, they do work all the time, and from the inside), and/or of the direction of arena rules and game rules. But sustainable outcomes can also be the effect of properties of technological systems and their socio-technical linkages, somewhat independently from the intentions and rules under which they were developed and set in motion. Thus, meso- and macro-level phenomena in which technology plays a constitutive role must be considered as well. These phenomena are in fact a further set of only partially visible hands, working through the gradients of force involved. (Also, the work of scholars in technology studies can be seen as an attempt to make such patterns and gradients visible.)

There are two sides to these socio-technical dynamics. One, the way technical change evolves and spreads, in interaction with existing regimes, industry structures, and societal structures generally. Two, how this shapes society, as well as further socio-technical change. Rip and Kemp, in their 1998 synthesis, introduced three levels at which socio-technical change is played out. A visualization is offered in Figure 2.2. While it does not include industry structures and other patterns in society, it highlights the concept of 'socio-technical landscape', another invisible hand creating gradients of force in the same way as a physical landscape.

Technological regimes are grammars, or rule-sets, which orientate (up to disciplining them) the work of engineers and other actors developing new technological artefacts and systems (cf. Nelson and Winter, 1982; Van de Poel, 1998), but can be broader and shape the interactions of actors with the relevant artefacts and systems and how these are embedded in society. Staudenmaier (1989) shows this for the motor car and the maintenance of the transport regime building on the motor car. What Figure 2.2 adds, in line with the work of historians of technology like Staudenmaier, is the sedimented landscape resulting from earlier actions and cumulating infrastructure, which changes only slowly, the *longue durée* as Braudel (1966) called it. Like regimes, the socio-technical landscape enables and constrains, but not through rules.

Notes:

1. Novelty, shaped by existing regime.
2. Evolves, is taken up, may modify regime.
3. Landscape is transformed.

Figure 2.2 The dynamics of socio-technical change

To show the importance of (socio-)technical regimes and socio-technical landscapes as invisible or only partly visible hands, we briefly discuss two examples. First, the infrastructure of electricity generation and use, including networks and billing systems. This is how electricity has become embedded in society, and how its use has become so important that it is an almost obligatory passage point for fuels and other energy carriers in order to reach end users. In other words, there is a buffer zone or layer in the socio-technical regime plus landscape which separates ongoing innovation in technologies to generate and distribute electricity, from innovations at the distribution and use side. In terms of the quasi-evolutionary theory of technological change, one could say that selection is constrained, because it must work through the buffer zone, but the range of variation is contained as well because it must always lead to, or utilize, electricity. In other words, a *nexus* has emerged, now at the macro-level. This enables productive socio-technical work, within the limits set by the nexus. Alternatives to electricity stand little chance, at least in the short term.

In other words, 'function', what is done with electricity, how it is distributed, is separated from 'form', how to generate electricity. The buffer layer, because of its position, has socio-technical power, and alternative approaches

run against it. Whatever alternative technological option is chosen, it must be mostly shaped so as to be (also) able to deliver to the grid. The implication is that technological regimes of wind energy, co-generation and so on have to relate to the dominant regime, at least to the buffer part of it. Of course, each alternative technology has its own research agenda, but issues of grid connection and load management shape this. Behind the functionally defined electricity supply regime there is a mosaic of technological regimes. These compete among each other, but in a situation pre-structured by the historically evolved shape of the electricity supply regime. The regime of electricity supply is also connected with materials regimes. Improvements in the energy efficiency of steam turbines and gas turbines were achieved mostly through the use of better materials that allowed for combustion at higher temperatures. Technological regimes are thus connected with each other; they mutually shape each other. The demand for high temperature resistant materials for electricity generation shaped the research agenda of the material's regime.

The second example, of the transport and mobility regime focusing on the motor car (mentioned already as an example of a socio-technical regime), is much more heterogeneous than the electricity regime, and could perhaps better be seen as a set of overlapping regimes. These are tied together, however, by the reliance on vehicles using explosion motors. One can see a buffer zone again, less homogeneous than in the electricity sector, but still enabling further innovation while constraining it in particular directions.

Understanding the dynamics of such macro-regimes helps to identify possibilities of modulating the development in desired directions (whatever these are). In particular, one could ask the question, are buffer zones to be welcomed? As with other nexuses they allow productivity, but constrain it in certain directions. Limited malleability of socio-technical regimes and landscapes is a fact of life. Transparency, making the nature of these invisible hands visible, helps to make expectations about what can be changed more realistic, but does not indicate directions of change.

A similarly fatalistic message is apparent in the work of Freeman and Perez on techno-economic paradigms and their version of the Kondratieff cycles. Freeman (for example, in Freeman and Perez, 1988; Freeman, 1992) has introduced the notion of a techno-economic paradigm to capture the effect of what he calls a pervasive technology, that is a technology which changes not only its own sector, but also the whole economy because of the pervasive effects in many sectors. One can argue that steam power, coupled with iron and steel, constituted the techno-economic paradigm of the railway (and steamship) age. During the period in which such a paradigm is dominant, other technologies (in this case, electricity) develop that will characterize a subsequent paradigm. In retrospect, one can speak of a mismatch of the new technologies and the socio-institutional context shaped by the dominant

techno-economic paradigm. For the present period, Freeman sees the new information and communication technologies as the emerging techno-economic paradigm of the 1990s and later decades. This is not so much a question of wealth creation (compare the productivity paradox), but of changing structures and interactions. One example would be the new possibilities for co-production when information exchange is not limited by geographical distance.

Overall developments in this period can be characterized as (much) more of the same: government bureaucracies continue to expand in the 'welfare' and 'warfare' state, education (at increasingly higher levels) spreads, professions and services grow. It is only towards the end of the period (as Freeman and Perez distinguish it) that growth, as well as the confidence in growth, hesitates. Diseconomies of scale appear, inflexibilities of the Fordist regime and limitations of hierarchical control; and (not mentioned by Freeman and Perez) the recognition of resource limitations and the vulnerability of the environment, which sets a new agenda for governments and also for firms. At the same time, the promise of new information and communication technologies is recognized, and speculations about the 'global village' appear – as an unintended counterpoint to the new perspective on the finiteness of the earth and its resources (up to the spread of pictures of the earth as a blue and green globe in space). Freeman and Perez take the former as the starting point for their characterization of the new period, from the 1980s and 1990s onward, as the 'information and communication Kondratieff'.

Freeman and Perez emphasize paradigm changes at the macro-level, and rightly so, but downplay long-term secular changes. Mechanization and then automation have often been identified as an important overall trend, and Beniger (1986) has added control, as a challenge and as a response with its own features (and sometimes problems, as when centralized control is not able to achieve the often locally necessary repair work). Another trend, highlighted by some commentators, concerns the successive shifts from mechanical to energy to information as key factors, which is then taken as an indicator of a trend towards dematerialization. As Grübler (1994) phrases it, the 'industrial metabolism' of our society is changing.

Industry has built in an *inherent incentive* structure to minimize factor inputs. This is primarily driven by economics and by continuous technological change. Therefore, industry moves in the right direction, and the real issue is 'how to accelerate this desirable trend (..) [towards] *dematerialization* (..) and (..) *decarbonization*. (Grübler 1994, p. 56).

Grübler's quote may well be an instance of wishful thinking, given the continued importance of mechanics and energy, at the very least as the necessary substrate for information and communication. But his insistence on industrial metabolism is important, and complementary to our discussion of

the importance of socio-technical landscapes. Both are ways to identify patterns in the co-evolution of technology and society. Tracing such patterns and understanding their dynamics may allow us to help them along a little bit, and in the right direction.

Combining a variety of relevant (but disparate) literatures, two further points must be made about socio-technical patterns and their effects. The first point starts with what we would like to call the increasing role of 'software' in handling 'hardware'. Software development and use in computer technology is the obvious example, with the advent of programming languages in the 1950s as the key step. Using the concept of 'software' more broadly, one can see the advent of operations research, of 'traffic engineering' (in telephone networks) and the increasing importance of logistics also as examples of 'software'. The design and 'disciplining' of activities and organizations on the basis of blueprints are then also software in the broad sense. Just like computer software, this generalized software is engineered, and thus qualifies as technology.

The broader notion of software links up with the analysis of historians and sociologists of how people, organizations and society are monitored and disciplined with the help of technology. Michel Foucault (1998) has emphasized the 'normalizing' tendency in modern societies, and the way technology is implicated in it. Prisons are built in such a way that surveillance can be optimal. At first, such technologies are specific to the particular purpose. But surveillance becomes a generalized function: in hospitals, in armies, in shopping malls. And the engineering challenge shifts from the particular circumstances (the 'hardware') to ways to discipline people (the 'software').

Normalizing, we add, is also a way of articulating what is 'good' technology – one can see this occurring for environmental technologies. One indicator is the importance of expectations and symbolic features: no dirty chlorine in my food, or in the toys for my child, no products linked to genetically modified organisms in the shop. In other words, there are requirements about symbolic features that may dominate performance requirements. Another example would be the present trend towards integrated assessment (also for environmental technologies).

The second point starts from the observation of a shift from economies of scale to economies of scope (and now also economies of skill) as the joint outcome of industrial and technological developments (Chandler, 1990). This is not just a response to changing economic circumstances; the circumstances have themselves evolved partly because of new technology – hardware combined with software – think of information and telecommunication technology and the present fashionable interest in the 'new economics'. And it may well be part of a movement diagnosed by the historian of technology, Hughes. He showed (Hughes, 1989) an earlier tidal wave of technological ingenuity and enthusiasm in the USA, which created a particular form of modernity (with

hierarchical control orientation and tightly coupled systems). This may well be less appropriate to the present-day world, partly because of technological developments in the direction of distributed systems. More recently, he actually pleads for post-modern technology (Hughes, 1998).

It may be emerging already, under our own eyes; even if the hands involved, while visible as promoters of technology and contenders for economic dominance, may not work towards a situation of 'post-modern technology'. Distributed systems escape central control, and make it difficult for actors to appropriate the benefits of their intervention. They also create problems for actors who want to influence technological developments and socio-technical patterns in the 'right' direction. Normalization as such (even in the broad sense discussed above) cannot be the answer by itself. A new combination of post-modern technology and productive normalization has to be found.

CONCLUSION

The three panels of the triptych do not add up to a positive conclusion, as beloved by managers and policy makers: 'This is the way to do it, to achieve whatever goals you have set for yourself'. In fact, such recipes are illusory. Our conclusions start negatively: the possibilities of working towards a public interest directly are severely limited by the combination of focused (focal) actors and evolving patterns (the first and second panel of the triptych), and (socio-) technical dynamics add their own gradient of force (panel three).

Thus, economic incentives and technology 'forcing' are refracted by having to go through the mosaic of smaller and larger, partially invisible hands (the games and regimes and structures) before they can have effect on behaviour and interaction. Monitoring such structures and their hold on actors is obviously important, but may not increase action potential.

More positively, if change in the 'right' direction has a chance, it must be part of a concerted action at different levels. It must also accept the variety and heterogeneity of the situation, and adapt its goals accordingly. This is our advice to actual and potential change agents, be they government actor with a mandate in this direction, or self-styled spokespersons for sustainability or other 'good' goals. In particular, the role of ideographs (cf. panel two) has to be recognized: the way they structure (in their peculiarly unspecific manner) actions and interactions once they have become accepted (as in the cases of democracy and of sustainability), as well as the way they open up opportunities (as in the case of distributed and non-hierarchical (socio-)technologies which are named as such).

We have addressed the multi-level nature of the phenomena by emphasizing that change and shifts occur at all levels, and mutually influence each

other (the extended version of 'translation' in actor-network theory). While multi-level analysis of changes has been proposed (for example, Dansereau *et al.* 1999), it often proceeds by keeping one level constant, so as to make the complexity manageable – and the results are then less interesting (at least for our purposes). Modulation of ongoing (multi-level) dynamics (cf. Kuhlmann, 1998; Rip and Schot, 1999) is the challenge, and one which cannot be resolved once and for all because the circumstances will change.

Part of the problem, as well as of the solution, is how the many and visible hands are involved with technology and society, and help shape them, while being shaped themselves by earlier structures and institutions. While we introduced the societal construction of technology and its co-evolution with society into the equation,⁹ this was done by quoting work from economists, sociologists and historians of technology, without linking their work with the theories discussed in panel two. The theoretical challenge is to integrate the perspective set out in panel two (with its contributing theories) with the analysis of patterns in the co-evolution of technology and society offered in panel three.

We have positioned our analysis as conducive to the identification of new (and better) modes of governance. Thus, there will be a political element in our argument: what is the nature of such modes of governance and how might these be justified as 'good'?

The first panel, starting with a focal organization and its interactions, in the end draws a picture of interactive corporatism:¹⁰ public interest considerations are part of the interactions, outcomes depend on increasingly institutionalized linkages between relevant actors. From the point of view of political theory, this is a neo-corporatist arrangement. The possibility of new technology introduces a dynamic element, and actors cannot simply fall back on earlier mandates and territories. Thus, the corporatist arrangement at any one moment is the outcome of interactions, rather than being stipulated in a pre-structured constitution.

In practice, dynamic interaction is constrained by lock-ins (from interest and discourse coalitions to vested-interest networks), and this will create a *de facto* constitution: a set of rules and patterns-to-be reproduced in ongoing interactions, and with sanctions (of various kinds) being possible. There may well be occasions where the lock-ins which had emerged should be broken. This is what environmental spokespersons did in the 1970s and 1980s – creating new coalitions and attendant lock-ins at the same time. The argument would then be that the lock-ins, the *de facto* constitution, are not as productive as they should be.

Theorists of democracy will probably criticize the diffusion of the governmental role in interactive corporatism, and they may well be right. We are not inquiring into the functioning of democracy, however, but into the possibility

of a better technology in a better society. Our approach has the advantage of recognizing ongoing dynamics and their limitations, rather than projecting ideal situations as the basis for change action and concomitant learning-by-doing. A prospective theory of socio-technological change is probably impossible. Making smaller and larger invisible hands visible by sociological analysis is possible, and a step in the right direction.

NOTES

1. This possibility is addressed in a major research project at the University of Twente (in collaboration with MERIT, University of Maastricht), on the Management of Technology Responses to the Climate Change Challenge, funded by the Dutch National Research Programme on Global Air Pollution and Climate Change. See Dolfsma *et al.* (1999) for a first background chapter from this project. Both authors participate in the project, and we will use the theme of the project throughout the chapter as example and empirical reference.
2. Our use of the term 'visible hands' is inspired by the title of Alfred D. Chandler's (1977) book, *The Visible Hand*, in which he analyses the emergence of modern management in corporations.
3. CTA agents are actors who work for a better technology in a better society by stimulating anticipation of effects of feedback into technological developments. A key feature of CTA, whether facilitated by CTA agents or occurring 'naturally', is the emphasis on anticipation, feedback and learning. There is, furthermore, an interesting (subterraneous) link to evaluation studies, and the movement to include 'stakeholders' in evaluations commissioned by a government authority (cf. Guba and Lincoln, 1989; Huebner and Betts, 1999). In the case of an educational or welfare programme, 'stakeholders' would be direct and indirect users, involved actors, and beneficiaries. The USA Office of Technology Assessment, in its time, developed an explicit stakeholder approach to the evaluation of new technologies, but did not include the interactive learning that is emphasized in CTA and in fourth-generation evaluation.
4. Garud and Ahlstrom's (1997) analysis of cochlear implants is a very good example. Marketeers might object that every product splits the market (there will always be market segments). The split discussed in the main text crosses traditional market segments, however.
5. This assumption (not discussed by Hart) should be turned into a question for empirical research. Analysis in terms of ideographs will be useful (cf. the second panel of the triptych), as well as considering 'third parties' (including big suppliers and insurers – examples of actors who will have, from their own position and interest, a longer-term view of socio-technical change).
6. Bower and Christensen (1995), and Christensen (1997), also discuss 'leaps', but focus on (uncertain) future competitive advantage promised by a new technology.
7. This is a further variation on the aphorism 'People make their own history, but they don't know which one' – Jorge Semprun's variation on Marx: 'People make their own history, but not under the conditions of their own choosing'.
8. Van de Poel (1998) has analysed such processes in detail, showing the importance of (credibility) pressures on existing regimes and the exemplary effect of a newly developed artefact embodying new (sustainable) functionalities. Dolfsma (in Dolfsma *et al.* 1999) used these analyses to argue that frictions and tensions in existing institutions would create receptivity to novel technology (whether sustainable or not). Cf. also Hoogma (2000) on the gradual opening up of the motor car regime to alternatives like electric vehicles, even if their actual use remains limited to niches.

9. We use the term 'societal' rather than 'social' on purpose. First, because it captures our approach, as will be clear from the analysis in this chapter. Second, because the 'social construction of technology' (SCOT) is a different theoretical approach (Bijker, 1995), with certain limitations (in particular, the undefined nature of the key concept of 'socially relevant groups') which make us hesitant to accept 'social construction' as a label for a productive approach to the *problématique*.
10. This term has stronger political overtones than the presently fashionable term 'policy networks', but seems to us to capture the situation better.

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