P. Weaver, L. Jansen, G. van Grootveld, E. van Spiegel, Ph. Vergragt, 2000, Sustainable Technology Development, Sheffield: Greenleaf Publishers, chapter 3 – Technology and technological change.

Abstract

The purpose of this chapter is to review studies of technological change in order to provide insight into how public programs that stimulate sustainable technological change should be designed. It first elaborates on the concepts of technology and innovation. Secondly, technological change and diffusion of technology are discussed. Third, the lessons that can be learned from those studies are summarized with special attention for environmental issues. In the conclusion, several recommendations are offered for technological innovation and change stimulating policy design.

The chapter starts with claiming that government involvement in technological change is necessary to steer technology towards preferred goals. Technology is approached in a broad sense including knowledge, cultural artefacts and institutions which, taken together, form a 'techno-economic paradigm'. From this perspective, technological change is a complex process of co-evolutionary dynamics – invention, innovation and selection - in the techno-economic paradigm. A process which is, according to the authors, facilitated by discoveries in basic science.

A two tiered view on technological change is derived from theories developed by Schumpeter and Usher. The former can best be characterized as explaining radical technological change and emerging discontinuity and disequilibrium. The latter describes incremental change and optimization through competitive pressures, cumulative knowledge and learning processes. The theories are considered complementary instead of mutually exclusive. Of importance to both theories are the limits of technology. These limits include both physical and configuration or context dependent boundaries, of which the latter are considered to be more constraining and pervasive. The concept of technological limits is essential because limits only show up as they are approached, indicating the end of improvement options.

Technology diffusion is a second important concept discussed. The authors stress that diffusion, either pure or replacing, is a long-term process possibly stretching over decades. This implicates an important lesson for policy makers who wish to influence technological change. Particularly when environmental burdens, caused by existing or diffusing technologies, should be reduced, long-term efforts are required.

Following Schumpeter attention is drawn to the effect of synergetic clusters of related innovations (technological, institutional, organisational, managerial) (as more important than one individual innovation/technology) in influencing the pathway of social-, economic- and environmental development. The historically observed fast-slow pattern of development (rapid growth, restructuring of the economy, followed by slower growth, stagnation and finally even recession.) is linked to the introduction of synergistic innovations.

From studies into the relationship between technological innovation and the patterns and pathways of economic development processes, several key themes emerged. First is that the history of development is marked by a succession of phases. These new development processes are based on past solutions and decisions, they have evolved out of the former phases of development and are influenced by it (path-dependency).

Achieving a technological transformation which reduce the claim on eco-capacity would be easier to introduce when an established phase of development comes to its end (reaches it limits or an 'innovation lethargy'). Despite of inertia (due to the systemic complexity of the established regime of accumulation) history shows that a succession of regimes will come. As technological and structural change will happen then anyway, directing this change to desirable social objectives is a matter of influencing the change and ensuring that the change in this broad direction proceeds at a sufficiently rapid pace.

Technology and the environment have a two way relationship. At the one hand technologies use resources and impose environmental stress, while at the same time technology is a response to resource constrains and environmental problems. In a historical perspective technological change has shifted the resource base of production, which has relaxed (perhaps only temporarily) some constrains while simultaneously making other, less immediate constrains more important. These influences of technological change on organisation and size of the markets, indirectly added to the overall claim on eco-capacity and increased society's longer-term vulnerability to new constrains.

The relationship between the environment and technological changes has implications for our understanding of biophysical limits and their interrelation with other forms of limits, including technical and institutional limits. Since humans needs and wants are influence by what is possible and affordable, they co-evolve with the development of technology and the level of affluence. Limits are therefore not imposed by biophysical factors alone but rather by a complex and dynamic interplay involving environmental capacities, technological capacities, institutional capacities and culture.

Improvements in the eco-efficiency of individual technologies will not automatically translate into a lower overall claim on eco-capacity, which has implications for the term 'sustainable technologies'. Along with the attributes of a technology, the applications context determines the eventual environmental stress it causes. A primary function of technology assessment is to estimate in advance the limits on the scale of use that are compatible with sustainability and to modify the subsequent evolution of the technology so as to moderate the growth of its impact with the scale of use. This stresses that technology diffusion and use are as important as innovation and design issues. It also implies that technology can not be the solution, of itself.

Technological development is an inefficient process. Successful technological development depends heavily on decentralised decision making structures and processes of information exchange. Markets and informal information networks among technology suppliers and users are important to the processes of weeding out inferior technologies, selecting superior alternatives and learning how to improve these. Over time and through communication among its members , a network develops a 'joint-technological expectation', under influence of shared understanding, visions and missions (these expectation may be come self-fulfilling).

On the relationship between technological development and competitiveness it is worth noticing that most successful companies are the ones that invest in incremental change in the short run, but also invest in the long term, strategic planning and R&D breakthrough technologies. Another lesson is that early innovators typically dominate their industry over long periods of time. The key of to a pioneer's advantage lies not in having 'good' technology, but 'better' technology and always keeping ahead in the technology race by making use of the learning opportunities of leadership to keep ahead.

Despite efforts to induce sustainable development, results are not that promising. A large part of the reason for this is that incentives are distorted, operational control is fragmented and short-termism is institutionalised by today's arrangements. Shifting the balance of R&D efforts in favour of radical innovations is needed. Due to underinvestment issues of companies when the major beneficiary is the public, public support is needed. A criterion for this is that the social benefits should be significant in relation both to the cost of support and the privately appropriable benefits. Private firm are likely to under-invest in the face of high market uncertainty or if the benefits of their R&D investments are difficult to protect against 'free-riders'.

This chapter conclude with drawing forth the lesson learned and positioning them as design principles of a programme aimed at inducing sustainable technologies. The broadest implication might be that the role of the government is to influence technological and development trajectories indirectly, by encouraging innovation in respect to the innovation process itself, rather than by picking up and backing prospective technological winners. In effect, firms and networks should be the key organisational entities and decisions should be

taken in decentralised decision-making structures. In addition, a public policy programme needs to be constructed as a ‘learning-by-doing’ activity, with a charter to evaluate its own performance so as to leverage its own effectiveness.