Available online at www.sciencedirect.com
ScienceDirect
Technological Forecasting & Social Change 74 (2007) 413–432
Technological Forecasting and Social Change

# Functions of innovation systems: A new approach for analysing technological change

M.P. Hekkert [a,*], R.A.A. Suurs [a], S.O. Negro [a], S. Kuhlmann [a,b], R.E.H.M. Smits [a]

[a] *Utrecht University, Copernicus Institute for Sustainable Development and Innovation, Department of Innovation Studies, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands*

[b] *Fraunhofer Institute for Systems and Innovation Research ISI, Breslauer Strasse 48, 76139 Karlsruhe, Germany*

Received 18 October 2005; received in revised form 2 March 2006; accepted 2 March 2006

**Abstract**

The central idea of this paper is that innovation systems are a very important determinant of technological change. We describe that the emergence of a new innovation system and changes in existing innovation systems co-evolve with the process of technological change. Therefore, it is necessary to create more insight in the dynamics of innovation systems. Traditional methods of innovation system analysis that mainly focus on the structure of innovation systems have proven to be insufficient. Therefore, we propose a framework that focuses on a number of processes that are highly important for well performing innovation systems. These processes are labeled as 'functions of innovation systems'. After explaining this framework and embedding it in existing literature, we propose a method for systematically mapping those processes taking place in innovation systems and resulting in technological change. This method can be characterized as a process analysis or history event analysis. Clarifying examples are taken from the empirical field of Sustainable Technology Development.


*Keywords:* Transition management; Innovation system dynamics

## 1. Introduction

There is a strong need to influence both speed and direction of innovation and technological change. In this paper, when using the concept of technological change, we do not refer to technology

* Corresponding author. Tel.: +31 30 253 6112; fax: +31 30 253 2746.
*E-mail address:* m.hekkert@geo.uu.nl (M.P. Hekkert).

0040-1625/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.techfore.2006.03.002

development in the narrow sense, but to the development of technology in interaction with the system in which the technology is embedded. We call this joined and interactive process the *innovation process*. An innovation can be defined as the successful combination of hardware, software, and orgware, where orgware refers to the various components of the innovation system [1]. Increasing the speed of innovation is important, since innovation is a key determinant for long term economic growth and development. Increasing the innovation speed at a national level is a highly complicated process, yet influencing the innovation direction is even harder.

The necessity to shape innovation processes can be demonstrated by the fact that apart from the advantage of creating economic growth and societal benefits, current use of technologies often have severe negative side effects. Quite often these negative side effects are related to the impact of technology on the natural environment. The relation between technology and the environment is complex and paradoxical [2]. On the one hand, technologies use resources and impose environmental stress. On the other hand, technologies can also lead to a more efficient use of resources, less stress on the environment and even cleaning of the environment.

The latter is often referred to as Sustainable Technology Development [3]. Technology development is not an autonomous process and, therefore, management of technological change is necessary. The design and implementation of these management processes is a key issue in many national environmental and innovation policy programs.

In order to make technological change sustainable, technical change alone is not sufficient. Changes in the social dimension–such as user practices, regulation, and industrial networks–are inevitable [4]. The recognition of this system level of change has led to a rapid diffusion of concepts such as technological transition [4] and industrial or socio-technical transformation [5].

Both science and policy community recognize ever increasingly that technological change and its resulting innovations are best understood as the outcome of innovation systems [6]. The concept of 'innovation systems' is a heuristic attempt, developed to analyse all societal subsystems, actors, and institutions contributing in one way or the other, directly or indirectly, intentionally or not, to the emergence or production of innovation. If we knew what kind of activities foster or hamper innovation–thus, how innovation systems 'function'–we would be able to intentionally shape innovation processes.

The use of the innovation system framework to understand technological change, has two shortcomings. First, even though this framework is based on theories such as interactive learning (e.g., [7]) and evolutionary economics (e.g., [8]), most analyses of innovation systems are quasi-static in character. There is a focus on comparing the *social structure* of different innovation systems (actors, their relations, and institutions) and, thereby, explaining the differences in performance. Less emphasis is put on the analysis of the dynamics of innovation systems. Second, the explanatory power of the framework lies mainly in the part of institutions (macro level), and less on the actions of the entrepreneur (micro level), even though an often quoted rationale behind the concept of innovation systems is that 'innovation is both an individual and a collective act' [9]. One might say that the innovation system framework suffers from institutional determinism; this is problematic, since the individual perspective–especially that of the entrepreneur(s)–is fundamental in practically all innovation literature. The entrepreneur is even likely to (now and then) overthrow and change (parts of the) structures around him, thus forcing the process of technical change into new directions.

Since technological change is a dynamic process, which requires a transformation of the innovation system in which changes take place, a dynamic innovation system approach is needed to understand and better be able to guide its direction. The basic notion of this paper is that by applying the innovation