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Sequencing the evolution of technologies in a system-oriented way: The concept of technology-DNA

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ABSTRACT

T-DNA is a new method for characterizing technological fields by means of patent classifications and analytical coding. In this method, technological fields are disaggregated into four system levels. Patent activities within technological fields are classified with respect to these system levels. A sequence of dominant system levels over the course of time emerges. As we see a strong analogy between this and the DNA-sequence of living organisms, we refer to this method as technology-DNA. Technology-DNA is applied in a case study in the logistics industry, in which we find that inventive activities focus on system components and associated systems.

Introduction

Technological evolution and its growing impact on business have intensified the need for adequate measures and methods for the analysis of technological fields. As technological fields can be seen as dynamic systems (Murmann and Frenken, 2008), the analysis of such fields has to take account of a multiplicity of system components. A common feature of the analysis of technology evolution so far is that the focus is set on technological fields as a whole. Conventional methods of analyzing the evolution of a technological field, stemming from technology life cycle models like those by Ford and Ryan (1981) or Linden and Fenn (2003), concentrate on core- and subsystem levels. Although much

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insight can be gained by these methods, this can be seen as a shortcoming as the analysis of different levels of technological systems may yield new insights into their evolution and a more comprehensive view of their structure. Consequently, we introduce a method of analyzing technological fields which is based on a differentiation between four different system levels within technological fields, including the core system, the supersystem, the subsystem and the associated system level. This allows for a precise examination depending on components as well as on the context of technological fields. By measuring the technological activities within these four systems levels with the aid of patent analyses, the dominance of the system levels is examined over time and represented in the form of technology-DNA (T-DNA).

The remainder of the paper is organized as follows: after providing an overview of technological fields, their structure and measurement, section 'Theoretical background for the model of technology-DNA' contains an introduction to the underlying model of T-DNA which defines technological fields as a system comprised of four system levels. In section 'The method of technology-DNA-retrieval in general and applied', the method of T-DNA-retrieval will be described in detail. Section 'Findings in the test application of 'inventory management'' will show the findings of a T-DNA-retrieval for patents from the logistics sector (in particular: inventory management) and discuss the results. Furthermore, T-DNA will be compared with another measure based on patent classification in section 'Dissociation from other measures'. Conclusions and topics for further research will be addressed in section 'Summary and conclusions'.

Theoretical background for the model of technology-DNA

Prior to developing the T-DNA of a technological field, it is necessary to look into the background of this field in terms of its definition, structure and evolution. The following chapter will deal with the questions: what is a technological field and how is it organized? What is our basic understanding of a technological field's evolution? How can the evolution of technological fields be measured? How can patents help to analyze technological fields?

Definition of technological fields

Literature on technology evolution contains various definitions of technological fields (see Table 1). Following and expanding these definitions, we understand technological fields as systems that are organized on four system levels: core system, subsystem, supersystem and associated system, of

Table 1
Different perceptions of technological fields and their development.[a]

Perception technological fields	Authors
Technological fields are complex multilayered systems; hierarchically organized; mostly having multiple levels of subsystems; each of this hierarchy levels can pass its own technological cycle	Murmann and Frenken (2008); Tushman and Murmann, 1998
Technological fields develop in an evolutionary manner; hierarchical structure	Clark (1985)
Interdependencies among parts of the technological field result in a trajectory-like development of the field	Hughes (1983); Frenken et al. (1999)
Technological trajectories: temporal sequences of technological innovation; resulting in product or process innovation	Graff (2003)
Technological fields are composed of linked subsystems; within a technological field different trajectories compete for dominance	Suarez (2004)
Technological fields are focused on the development, diffusion and use of a particular technology; often international; contain different components that influence the evolution of the technology; may cut several sectors or be a subsystem of a single sector	Bergek et al. (2008)
Technological fields are networks that evolve over time in terms of varying types of actors and institutions; many of these fields are present in every country	Carlsson et al. (2002)
Technological fields are recognized areas of technology; specific sets of components, which are repeatedly partitioned into systems; hierarchies of subsystems and components	Peine (2009)

[a] The original wording of Murmann and Frenken (2008), Tushman and Murmann (1998), Clark (1985), Hughes (1983) and Frenken et al. (1999) refers to 'technology'. However, content-wise these definitions can be related to technological fields.