Technological convergence and the absorptive capacity of standardisation

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ABSTRACT

In this paper a method of identifying trends in technological convergence on the level of technical fields is proposed. Defining convergence as an inherently stable process of structuring inter-technological patterns over time, German patent data are used to project them onto the structure of the output of standards via a concordance list of International Patent Classifications (IPC) symbols and International Classification of Standards (ICS) classes. Using a set of criteria for a reliable measurement of technological convergence, a set of methods, such as explorative identification of agglomerations of technical fields, the analyses of the breadth of technical fields to differentiate between focused and diffused convergence trends and in-depth analysis using a revised version of the Cross-Impact Assessment method, are devised to measure the level and trend of technological convergence. The structures of convergence in technological development and standardisation are in general moderately positively correlated, but that there are significant differences on how these converging trends are covered in the stock of active standards at the level of technical fields.

1. Introduction

Technology convergence is a widely discussed phenomenon both among policy makers as well as among practitioners and researchers. Meanwhile, it is also discussed actively in terms of standardisation. This discussion addresses both standards as enablers for converging technologies as well as the challenges that arise from converging technologies for the standardisation process and the standard setting organisations. The importance of standards for convergence is apparent when standardisation is perceived as a process of selection by which technologies are transformed into the content of standards that "carry a cognitive or normative expectation to comply" [1] by a process that [2] metaphorically refers to as "pruning the tree". In this way

standardisation can provide stability and focus in terms of technology development towards technology convergence. Moreover, regulation and standardisation can become important factors for successful technology convergence by a harmonization effect between different technologies and industries [3]. This is especially true in early stages of technology convergence. In early stages of technology, standards can be an important success factor for complex technologies involving many subsystems [4]. [5] argues, that convergence spurs "new forms of inter-firm interaction, i.e. consortia formation, clustering, and collaboration within standardisation bodies".

The challenge of convergence for standardisation is also recognized among practitioners and standardisation organisations. Some standardisation bodies like the German national standardisation body DIN actively integrate technology convergence in their overall strategy [6]. [7] argues that convergence has been a trend for standardisation in the realm of information and communication technology (ICT) in the late 1990s.

The relationship between technology convergence and standardisation can also be confronted with patterns of division of labour in the standardisation landscape. Both on

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the international and on European levels the standardisation landscape is differentiated by a distinction between electrotechnical aspects, with the International Electrotechnical Commission (IEC) responsible on international level as well as the European Committee for Electrotechnical Standardization (CENELEC) on European level, and general standardisation aspects excluding electrotechnical aspects under the International Organization for Standardization (ISO) on an international level and the European Committee for Standardization (CEN) on a European level. This distinction in part is also reflected on a national level in some countries. In cases where the expected development of a converging technology is interpreted by the actors themselves as promising and invoking a paradigm shift,[1] standardisation races might occur which can obscure the relative legitimacy vs. speed trade-off as highlighted by [8,9] as well as having a negative impact on the quality vs. speed trade-off [10].

Even though it is argued that there exists an interrelation between technology convergence and standardisation, few attempts have been made to integrate technological convergence and standardisation in a unified analysis framework. Attempts like those of [11] integrate convergence in technology and standardisation in a way, that convergence of technologies can also lead to a convergence of standards and standardisation both on the level of standards themselves as well as on the level of institutions. They do not, however, develop a method for measuring the extent to which technology convergence is reflected in standardisation. Overall, there is little broad empirical evidence regarding the claim that there is a connection between the two realms, even though studies hint that in the realm of ICT the overall dynamics of technical change also are partly reflected in the structure of the output of standards [13].

In this paper a generalized method of measuring technology convergence and convergence in standardisation is developed by linking trends in converging technologies on the level of technical fields to standardisation to conclude in which technical fields standardisation is more likely to absorb converging trends based on past capacity to absorb trends that are situated across technical fields.

2. Concepts of technology convergence

According to [14] convergence "means different things to different people". Therefore, a comprehensive concept is required that can be used to develop a set of measurement methods of technology convergence universally applicable both in the context of technology development and standardisation. The first challenge is to integrate multiple concepts of convergence into a comprehensive approach that can be used for its measurement without missing already established key aspects.

Most of the literature on convergence implies that convergence is generally an enhancement over a previous technical solution by the realization of mutual interdependence on the level of product or artefact from different technical backgrounds, but having a larger impact beyond products just focusing on one technical field. In this sense, [15] frame convergence as an enrichment, i.e. increasing the potential of one technological application domain through

means of another application domain, thereby ultimately producing a whole new class of products, e.g. smart phones including digital cameras. The focus therefore is not on the individual product, but rather on a group or class of products. Also, the view implies a sense of directionality by concentration on convergence defined as its result of fulfilling the means of one application domain through enhancement of another application domain.[2] This directionality also implies that the resulting artefacts are not sui generis from the perspective of means that they allow to be realized, but can represent a substitute of a previous application domain. This view is consistent with the notion of evolution of dominant designs as introduced by [16,17]. From this perspective, technological convergence is the result of a specific form of dominant design which integrates distinct knowledge or innovation from another technology or industry sector [18,19].

Other papers highlight convergence as representing an erosion of boundaries between sectors or fields of technologies that increasingly blur together [12,15,20]. [21] highlights that "technological convergence" blurs the boundaries between industries in a sense that similar machinery and processes are being used over different sectors. This concept aims at a technology convergence that is most relevant in production and provision of goods or services. Other authors approach convergence from the perspectives of relationships between convergence and markets, i.e. convergence in technology leads to convergence in the market [22]. The image of blurred boundaries can be interpreted as a generalization of [23]. Their view also includes the notion of enhancement. The merit by [24] is that they allow a perspective which enhances the convergence concept by integrating directionality extending the concept beyond a binary perspective, i.e. beyond the relation between two sectors or technologies, towards a more generalized perspective. Still, their approaches also are fixed to a distinct starting point of observation, as in the case of General-Purpose-Technology (GPT) and are rather undifferentiated regarding potential end points represented by the industry sectors that are impacted by these converging technologies. In an abstract sense, this view frames convergence as the result of an interpretative flexibility as highlighted by works of sociology of science and technology (e.g. [25]). The interpretative flexibility of the GPTs is realized by a high degree of perceived usefulness by different groups of actors or industry sectors. Yet, these perspectives do not differentiate between convergence that is focused, i.e. a distinct entanglement of technology fields that are increasing in relative importance, or a diffuse sense of convergence, i.e. a technology field that increases in importance over a wide array of other technical fields.

Apart from the discussion on what accounts for the essence of convergence there is also a strong focus on ICT. The relevance of ICT in the context of technology convergence has been strongly influenced by ideas of an article by [26] in a Science Magazine titled "The Convergence of Computing and Telecommunications Systems". This notion of convergence is represented

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[1] On the notion of standards as paradigm enablers see [12].

[2] It has to be noted though that the term enhancement represents the subjective expected utility that technology developers attribute to the solution. In case of successful diffusion of technology this means that the relative increase in utility of new products over their predecessors is aligned between supply and demand side relative to the different technologies.