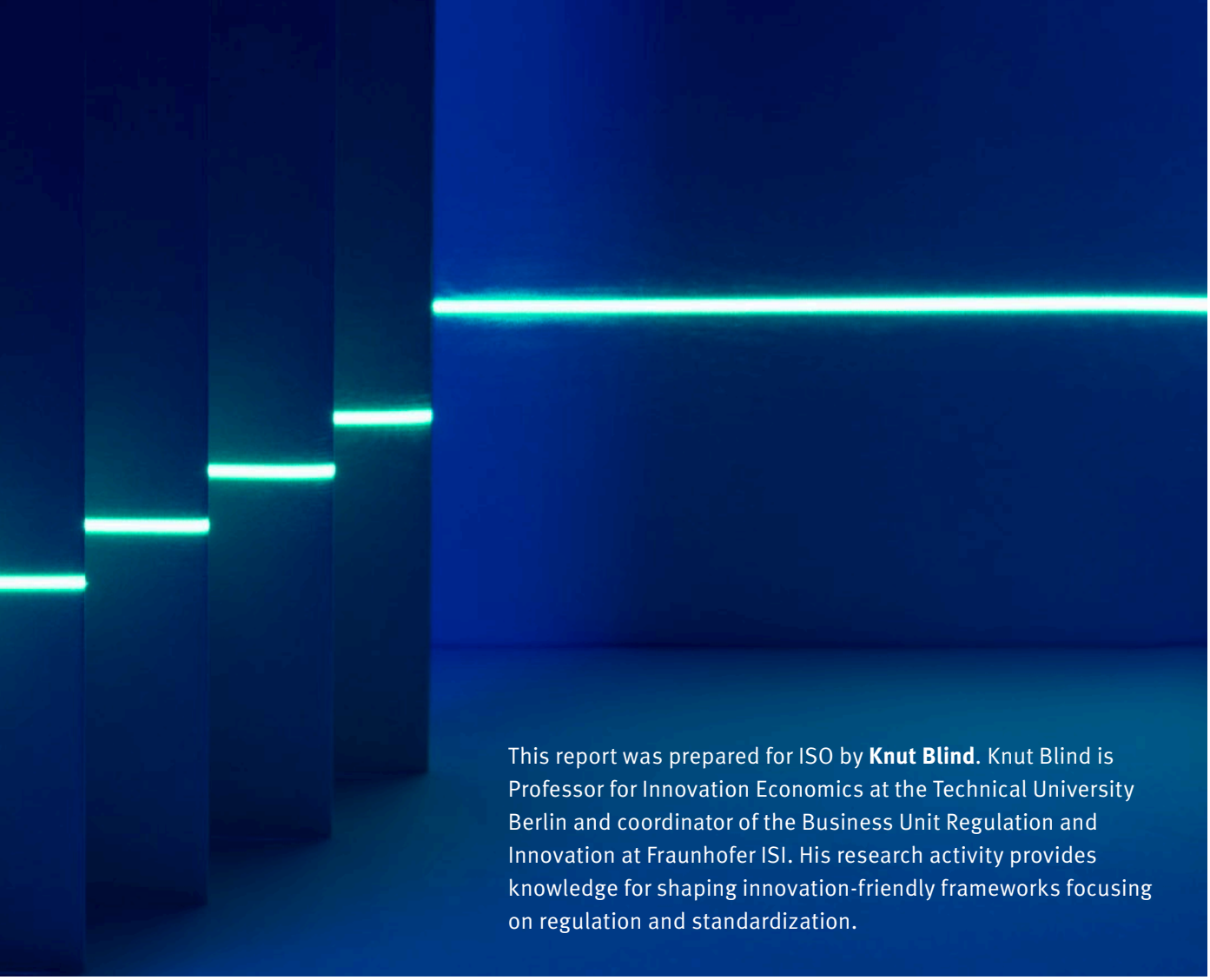
ISO research and innovation

Standards and innovation

What does the research say?

PAPERS



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Contents

Executive summary

Using a combination of academic research and case studies, this paper explores the relationship between standards and innovation and summarizes the current state of research in this area. In this paper, we take a broad understanding of the term "innovation" in order to reflect the multiplicity of definitions used in the literature and to provide an inclusive overview of the research.

Theory and evidence

There is a complex relationship between standards and innovation. The way in which standards impact innovation depends on their primary economic function and on the context in which they are used. In terms of their economic functions, some standards codify and share knowledge; some reduce the variety of goods, services or processes on the market; some secure quality; and others achieve compatibility. Whether these different types of standards impact innovation in a positive, neutral or negative manner can depend on the size and resources of the organization using the standards and the type and characteristics of the market in which they are operating.

- Standards that facilitate information sharing and codification of knowledge allow organizations to easily access knowledge that they would otherwise not be able to acquire. Organizations can then use this knowledge to support their innovation programmes. At the same time, information sharing can also create situations of unfair competition. First, screening standards for information can be costly, especially for smaller organizations with fewer resources. Second, knowledge spillover to competitors can reduce competitive advantage.
- Some standards contribute to reducing the variety of available technologies, products, services or processes on the market. With less options available, customers are driven to the same products, allowing companies to produce more units at larger scale with minimal input costs, thus lowering prices for customers. This can have both positive and negative effects on innovation. On the one hand, the incentive to reach a larger market (generate economies of scale) and save on input costs fosters research and innovation into complementary products and innovations (incremental innovation is promoted). On the other hand, promoting the deployment of some technologies through standards means that alternative, unfamiliar technologies might not be worth investing in as market success risks being limited (radical innovation is discouraged).
- When implemented appropriately, standards serve as a guarantee of quality, health, safety and sustainability in innovations along the supply chain. Standards promote trust between collaborators who can access the same up-to-date information on products and processes, thus reducing innovation-related risks. The catch here is that implementing standards might be more costly for smaller companies, which may constrain their ability to innovate.
- Compatibility standards safeguard the market success of innovative technologies and products in network-based industries (e.g. information and communications technology, ICT) through positive network externalities: the more people use such goods or services, the more their value increases in the eyes of other consumers/users who are more likely to purchase the same (or a compatible competitor's) product or technology. This advantage disappears, however, when compatibility standards are not International Standards but rather patents or industry standards protected by intellectual property rights, in which case a single player can end up monopolizing the market.

Recommendations based on findings: future research?

This paper highlights the obvious need for additional research to empirically investigate the relationship between International Standards and innovation.

- More precise and representative data about the diffusion and use of standards is required. This data needs to then be available and analysed, using clear and consistent methodologies (since assumptions about definitions and measures in existing research often get in the way of comparability between studies).
- Standards and innovation should not necessarily be approached as separate concepts, because research and innovation can act as catalysts for the development of standards themselves.
- New forms of collaborative innovation must be explored, focusing on a wider variety of organizations, not just companies.
- Finally, in order to draw systemic conclusions, more studies with broad scopes are needed to complement the targeted case studies making up most of the existing research. A wider variety of standards should also be assessed (including ISO 56000 on innovation management when more evidence is available for this recently published standard).

Introduction

Do standards enable or constrain innovation?

The notion that standards constrain innovation is a widely held popular belief because it seems logical – standards are seen as adding restrictions and leaving little room for the creativity and novelty necessary for innovation to thrive. And in some specific circumstances, this can certainly be true.

However, research shows that the relationship between standards and innovation is a lot more complex. Indeed, evidence suggests that standards can, in many cases, play an important role in enabling innovation, whether by providing information to drive innovation or creating incentives to innovate.

This paper will explore the complex relationship between standards and innovation, moving from the theoretical explanations of how standards can influence innovation, to the concrete evidence found by researchers so far, to potential areas of future research.

Defining innovation

Before considering its relationship to standards, it is first necessary to define "innovation". Everyone agrees that innovation is important, but it is harder to find agreement on what this concept actually means. Many definitions of innovation exist because of the influence of different scientific disciplines and scholars. One usefully broad definition comes from the Organisation for Economic Co-operation and Development's (OECD) Oslo Manual (OECD/Eurostat, 2018), which provides guidelines for collecting and interpreting data on innovation.

It defines innovation as:

"a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)."

The OECD collaborated with ISO's technical committee on innovation management (ISO/TC 279) to exchange perspectives on the definition of innovation. This

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resulted in greater alignment between the two organizations' definitions, taking into account the different objectives of the Oslo Manual and ISO standards. The OECD shaped its definitions to suit innovation measurement while ISO considered the requirements for standardization.

The definition of innovation given in ISO 56000, *Innovation management – Fundamentals and vocabulary*, is: a "new or changed entity, realizing or redistributing value."

This definition is narrower because it requires innovation to be the creation, or at least the redistribution, of value.

There are two main types of innovation: product innovation and business process innovation, which are defined by the OECD as follows (OECD/Eurostat, 2018):

- "A product innovation is a new or improved good or service that differs significantly from the firm's previous goods or services and that has been introduced on the market."
- "A business process innovation is a new or improved business process for one or more business functions that differs significantly from the firm's previous business processes and that has been brought into use by the firm."

Finally, an innovation may be differentiated according to whether it is new to the firm only, new to the firm's market, or new to the world. The latter type is more likely to become a radical innovation with the ability to change existing markets or create new ones, while the former will likely be just an incremental innovation.

The standardization process and innovation

This paper focuses on standards as an important factor for innovation. But what about the standardization process? It is now well recognized that standardization has the potential to stimulate innovation within and amongst companies. Participation in the standards development process can help companies to commercially exploit innovative ideas from their customers and learn from competitors and other stakeholders in the process. It also provides the impetus for them to communicate and disseminate their own innovations to other stakeholders and to absorb innovative ideas suggested by other participants in the standardization system.

Standards and innovation: theoretical impacts

Economic functions of standards

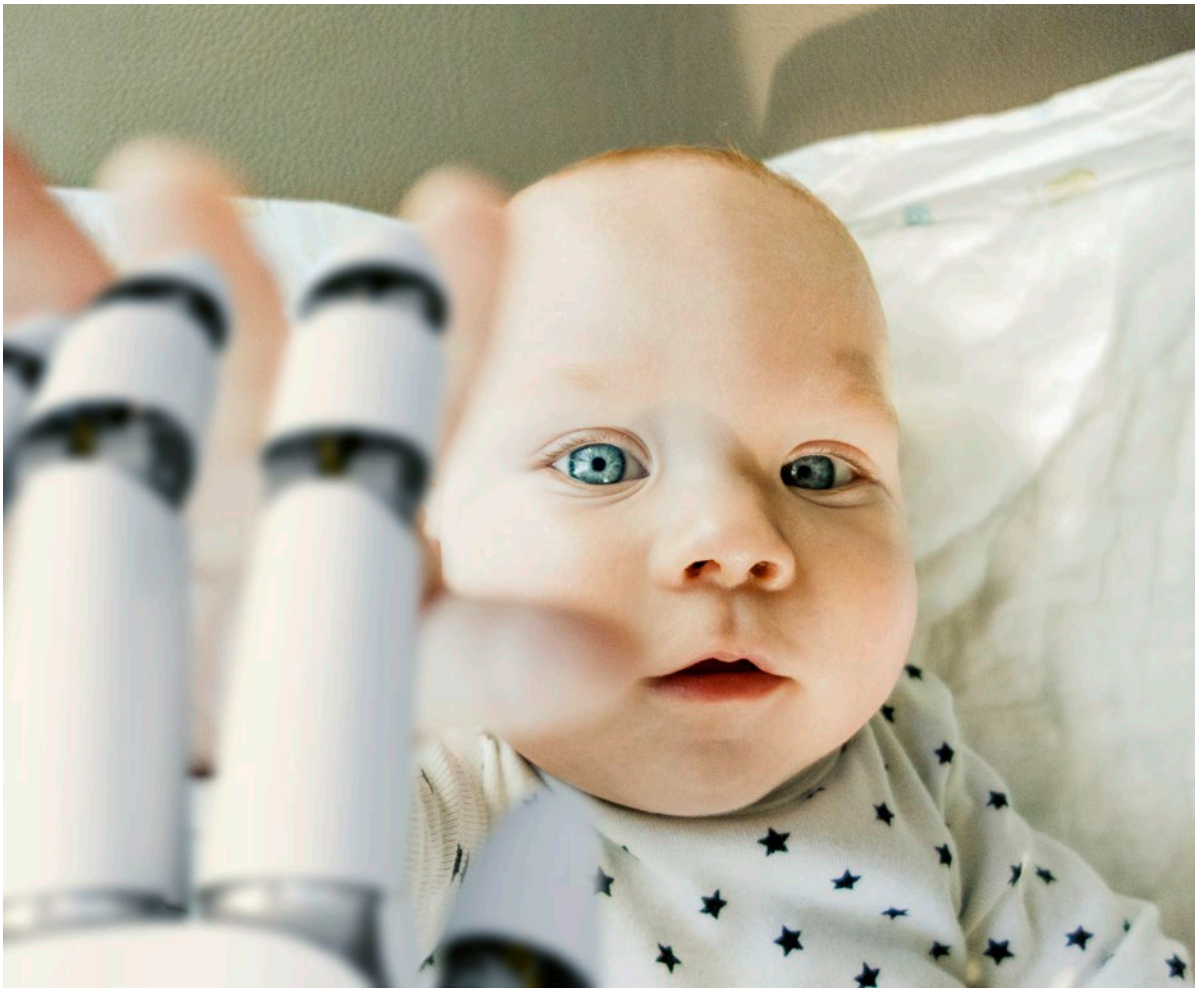
Before we take a look at the impacts of standards on innovation, it is important to provide some theoretical background on the generic economic functions of standards (David, 1987). An explicit overview of these economic functions was first provided by Swann (2000) who described the following four functions of standards: codifying knowledge, reducing variety, securing quality and achieving compatibility. These are discussed in more detail hereafter, ranked from the most basic to the most complex.

Codifying knowledge

As is the case with scientific publications or patents, standards codify knowledge by defining a set of rules that have gained authority through common consent. The knowledge they contain has gone through a consensus process as a means of incorporating the views of many different stakeholder groups, not just scientists or inventors. This codification of knowledge reduces transaction costs related to, for example, planning, deciding, changing plans, resolving disputes and after-sales. Such costs may accrue between different organizations or between actors within the same organization.

Reducing variety

Selected specifications prescribed by standards result in a reduction in the variety of technologies, products, services or processes on the market. The more specific and detailed the standard, the greater its potential to reduce variety. The variety reduction function applies to all types of standards to varying degrees. Placing the focus on a specific technology, product or process typically enables economies of scale to be achieved (i.e. the reduction of unit cost via mass production), eventually leading to lower prices.



Securing quality

This third function, which is not applicable to all standards, is concerned with defining a specific performance level for products and processes along one or more dimensions, such as health, safety or environmental impact. Standards that specify a minimum level of performance often allow for the development of market segments characterized by a higher level of quality because these standards mitigate information asymmetries between suppliers and customers. In addition, they reduce the risk of harm to consumers and workers, and also to the environment.

Achieving compatibility

A final function of standards is to ensure compatibility and interoperability between the components of complex products, but also of final network products such as mobile phones or social media applications. The focus on compatibility standards began with the emergence of ICT in the 1990s (David and Greenstein, 1990). Here, the standards generate direct positive network externalities, where the adoption and extent of diffusion depend on the number of existing users, and indirect network externalities, in which the widespread adoption of a technology depends on the existence of complementary products. One example of this might be the automotive market for electric cars where a dominant technical infrastructure is still missing. It is argued that the better the charging station infrastructure, the more potential buyers will be inclined to buy electric cars; conversely, the more electric cars are on our streets, the greater the demand for a proficient charging infrastructure.

The impact of standards on innovation

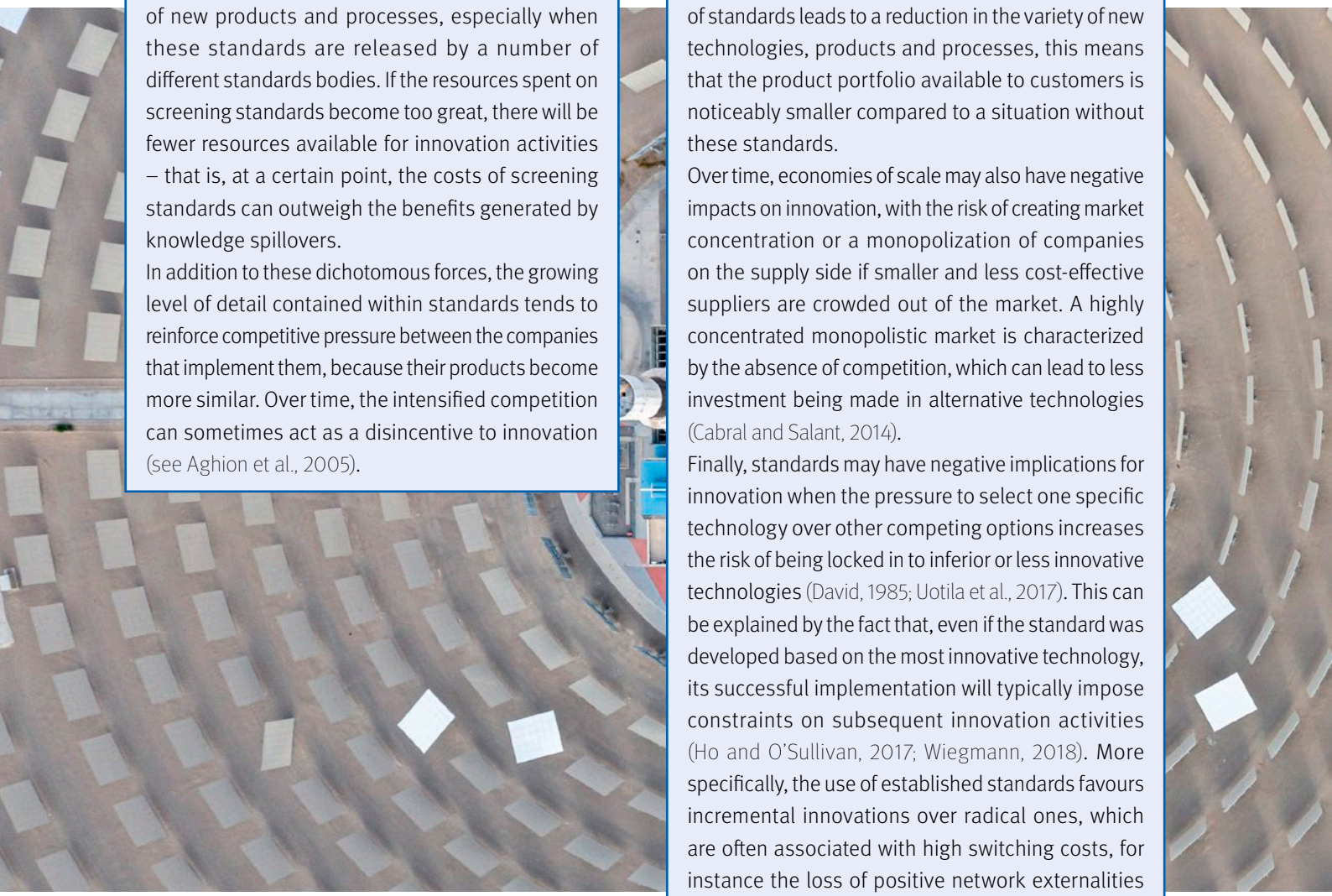
Because they are well-established and convenient to use, the economic functions introduced by Swann (2000) have become the basis for how we understand the theoretical implications of standards on innovation and emerging technologies (Blind, 2004, 2016, 2017).

CODIFYING KNOWLEDGE

As a basic function of standards, pure codification of knowledge can create knowledge spillovers which are used by companies and other organizations as input into their research and innovation activities (e.g. by relying on standards for plugs to create follow-up innovations). For example, standards help to coordinate innovation activities between companies in areas where they collaborate on projects that rely on the same set of standards.

As a rule, however, there is an optimal number of standards that can be used before the impact on innovation can turn from positive to negative. This is because there is a cost attached to screening and analysing standards for use in the development of new products and processes, especially when these standards are released by a number of different standards bodies. If the resources spent on screening standards become too great, there will be fewer resources available for innovation activities – that is, at a certain point, the costs of screening standards can outweigh the benefits generated by knowledge spillovers.

In addition to these dichotomous forces, the growing level of detail contained within standards tends to reinforce competitive pressure between the companies that implement them, because their products become more similar. Over time, the intensified competition can sometimes act as a disincentive to innovation (see Aghion et al., 2005).



REDUCING VARIETY

In nascent markets characterized by a large portfolio of emerging, technological opportunities, the timely development of a standard has the potential to generate a critical mass of manufacturers at the supply side. This prevents markets from becoming fragmented into many segments that are too small to be commercially viable. Standards therefore help new, innovative products get to market whilst helping companies exploit economies of scale, leading to lower prices and increased demand. They additionally help drive investment into research and innovation for complementary technologies and products.

However, variety-reducing standards can also have negative effects. When the successful implementation of standards leads to a reduction in the variety of new technologies, products and processes, this means that the product portfolio available to customers is noticeably smaller compared to a situation without these standards.

Over time, economies of scale may also have negative impacts on innovation, with the risk of creating market concentration or a monopolization of companies on the supply side if smaller and less cost-effective suppliers are crowded out of the market. A highly concentrated monopolistic market is characterized by the absence of competition, which can lead to less investment being made in alternative technologies (Cabral and Salant, 2014).

Finally, standards may have negative implications for innovation when the pressure to select one specific technology over other competing options increases the risk of being locked in to inferior or less innovative technologies (David, 1985; Uotila et al., 2017). This can be explained by the fact that, even if the standard was developed based on the most innovative technology, its successful implementation will typically impose constraints on subsequent innovation activities (Ho and O'Sullivan, 2017; Wiegmann, 2018). More specifically, the use of established standards favours incremental innovations over radical ones, which are often associated with high switching costs, for instance the loss of positive network externalities shared with other users (e.g. Arthur, 1989; Katz and Shapiro, 1992).

SECURING QUALITY

Properly implemented standards reduce the problem of asymmetric information between the supply and demand sides, e.g. information related to the quality of products and processes, or to their health, safety and environmental characteristics. In particular, standards can help instil trust among users and consumers by setting minimum-quality criteria for products and processes.

Innovative products and services and processes are usually associated with a higher level of risk because there is limited feedback related to their use. Standards have the means to significantly reduce the higher information asymmetries linked to innovative products, fostering increased trust. This is especially important for early adopters who are crucial for ensuring sustainable market success for new products.

The positive impact of quality standards is offset only by their implementation costs, which may be too high for many suppliers looking to place their innovative products and services on a specific market. The money they need to spend implementing quality standards could end up diverting valuable resources away from research and innovation, thus restricting innovative processes. Moreover, these costs may also create barriers to market entry, preventing a product from gaining traction in a new market and leading eventually to a monopolization of these markets, with the risk of curbing companies' innovative spirit, as discussed above.

ACHIEVING COMPATIBILITY

The market success of innovative products depends on the use of accepted compatibility standards in network industries, which are often based on ICT (David and Greenstein, 1990). Compatibility standards are fundamental to generating positive network externalities, which are crucial for influencing customers' value perception and their willingness to pay. In addition, innovative products can incorporate components from a range of different suppliers and, thus, are characterized by a strong demand for compatible interfaces. One example is mobile phones. Standards enable the different components in these complex products to work together, which also means individual components, such as semi-conductors, can be easily substituted for new higher-performing modules. In this sense, standards help to promote both incremental innovations and product diversity. The use of standards also ensures interoperability with the products of competing suppliers, as in the case of different mobile communication standards.

By allowing products to communicate across different generations of technologies and standards (such as 4G and 5G), compatibility standards can prevent lock-in with established technologies and older generations of standards characterized by strong network externalities. Rather, they provide the impetus for further investment in the development of standardized network technologies. However, this changes if the compatibility standards are not open, but protected by intellectual proprietary rights. In this case, the standards carry the risk of promoting not just monopolistic, but incontestable, market structures by exploiting opportunities that lie at the intersection of intellectual property rights and strong network effects. Such constellations have been used by dominant market players in ICT for many years and are still relevant today.

PROVIDING INSURANCE

Adding to these considerations about the economic functions of standards and their benefits for innovation, Foucart and Li (2021) propose that technology standards may be used by companies as an "insurance" to hedge against the risky process of developing new products (radical innovation). This means, concretely, that companies can rely on the solutions specified in standards when their own research and development or their efforts to commercialize new products have failed. However, this insurance option tends to reduce a company's incentive to invest in such radical innovation.

General functions of standards	Positive impacts on innovation	Negative impacts on innovation
Information	▸ Provide codified knowledge relevant for innovation ▸ Coordinate collaborative innovation activities	▸ Generate cost for standards screening ▸ Allow unintended knowledge spillovers to competitors by implementation of standards
Variety reduction	▸ Allow exploitation of economies of scale via standards ▸ Support critical mass via standards in emerging technologies and industries ▸ Create incentives for incremental innovation based on standards	▸ Reduce choice ▸ Support market concentration ▸ Push premature selection of technologies ▸ Limit incentives for radical innovation
Minimum quality	▸ Creating trust in innovative technologies and products at the demand side	▸ Promote market concentration
Compatibility	▸ Increase variety of system products ▸ Promote positive network externalities ▸ Avoid lock-in into old technologies	▸ Push monopoly power ▸ Foster lock-in into old technologies in case of strong network externalities
Insurance	▸ Serve as insurance against failure of radical innovation	▸ Create incentives for incremental instead of radical innovation

Source: Extension of Swann (2000) and Blind (2004, 2016, 2017)

Table 1 – Functions of standards and their effects on innovation

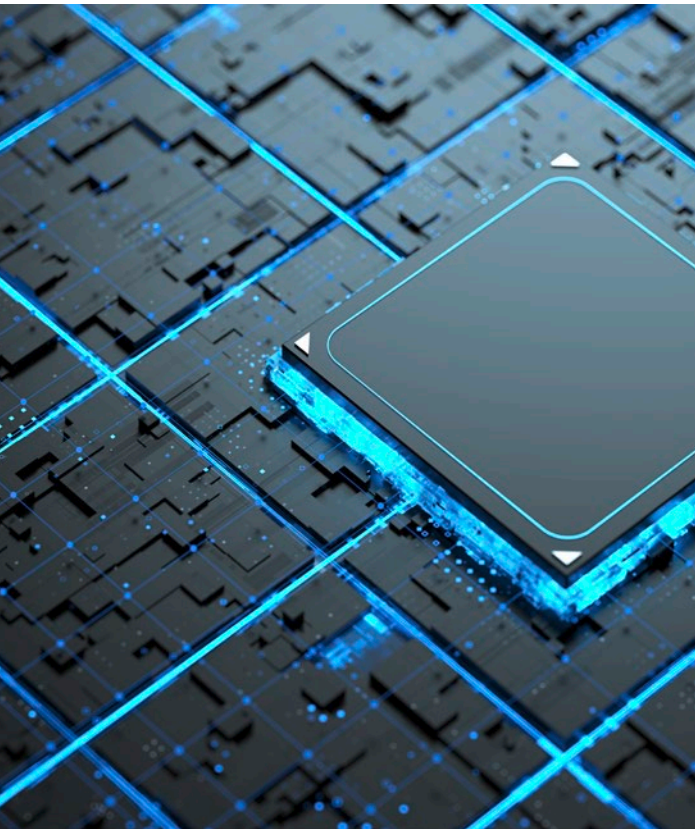
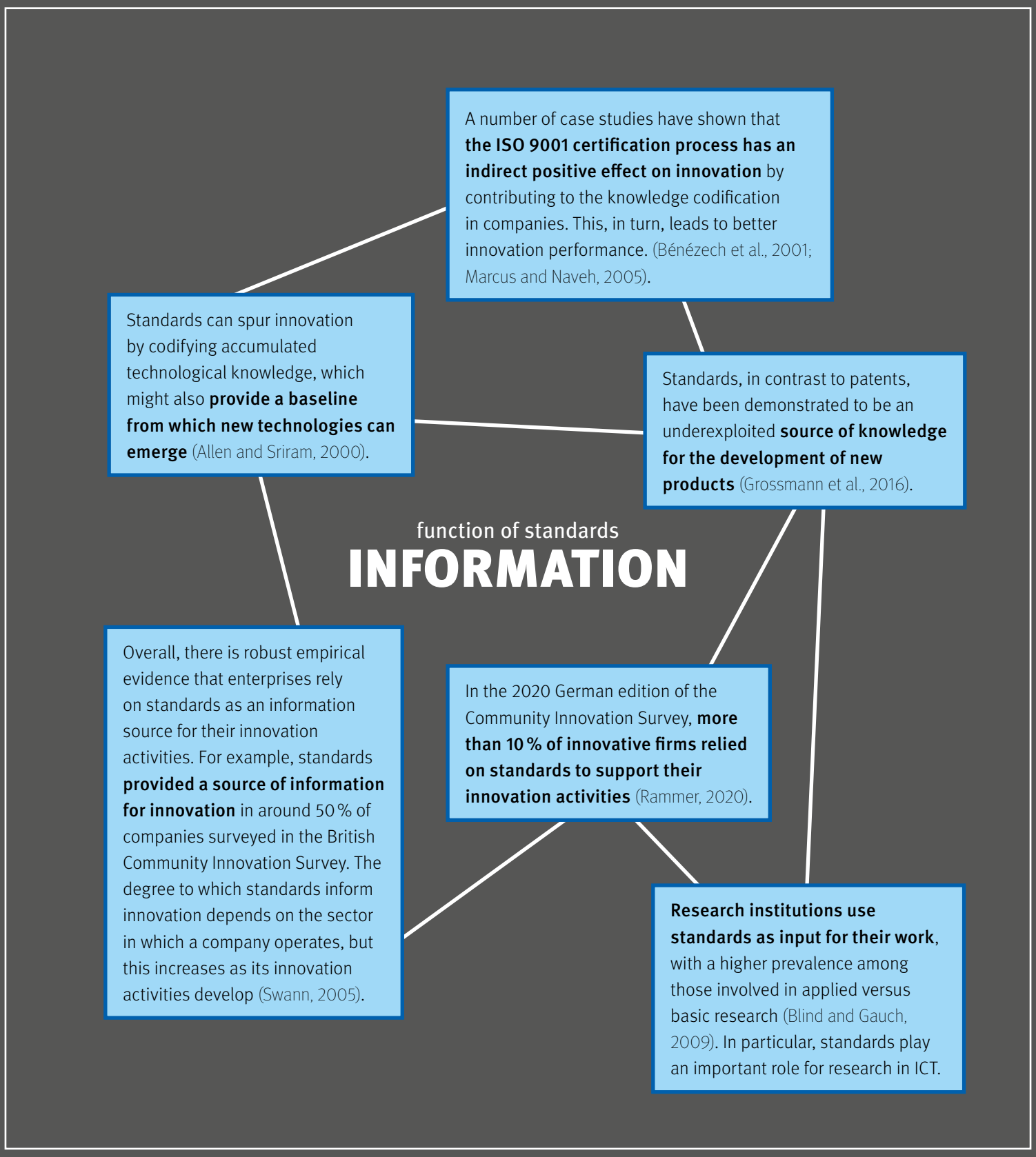


Table 1 compiles the theoretical impacts of different types of standards on innovation. In sum, the arguments supporting the positive impacts of standards clearly outnumber the list of potential negatives. However, this assumes the standardization process to be fully transparent, as advocated by the World Trade Organization (WTO), and a use of standards that is not hampered by inaccessible proprietary property rights such as patents.

Assessing the empirical evidence

Having reviewed the theoretical contributions of standards according to their different economic functions, we will now present some insights from important empirical studies whose evidence transcends case-specific observations. Some of these insights show positive impacts of standards on innovation, some show negative impacts and others show mixed or inconclusive impacts.

How standards affect a company's innovation activities and performance



How standards affect a company's innovation activities and performance

function of standards
VARIETY REDUCTION

The impact of the variety-reducing function of standards is difficult to determine because of the absence of counterfactual data.

The successful early adoption of GSM (Global System for Mobile Communications, a network compatibility standard for digital cellular mobile telecommunications) in Europe not only pushed the European roll-out of mobile communication, but also encouraged the follow-up and complementary innovations that brought success to some European companies (Pelkmans, 2001).

There are numerous cases of dominant (and mostly proprietary) standards which **reduce variety in the market and preclude the possibility of innovative alternatives** or follow-up innovations. Examples include the Video Home System (VHS) format that gained success over its rival Betamax for video recording and open compatibility standards like the pdf format. The theoretical prediction that **these standards favour incremental instead of radical innovation** is supported quantitatively by Baron et al. (2016).

An existing dominant design (e.g. supported by a specific standard) has been shown to **reduce an industry's degree of radical innovation** and overall innovative performance (Brem et al., 2016), in comparison to a situation where there are competing technological designs.

function of standards
COMPATIBILITY

ISO 56000 on innovation management systems was developed with the intent of fostering innovation efficiency in companies. However, its recent publication – it was released in February 2020 – means there is still insufficient evidence of positive impacts on innovation. Robust research results can only be expected at the earliest in five years.

Regarding compatibility standards, there are few studies in this field and none on specific ISO standards. The textbook example of a compatibility standard creating lock-in with old or inefficient technologies is the QWERTY keyboard layout, which has cornered the market despite the notoriously faster and more efficient layout developed by Dvorak. This is a good illustration of a situation where strong network externalities exist without there being compatibility to alternative designs (David, 1985; Arthur, 1989; Katz and Shapiro, 1992).

positive impacts of standards on innovation

mixed or inconclusive impacts of standards on innovation

negative impacts of standards on innovation

How standards affect a company's innovation activities and performance

ISO 9001 sometimes has negative impacts on product innovation, especially as relates to the development process and time to market of new products (Manders et al., 2016; Terziovski and Guerrero, 2014). This could be explained by high implementation costs of the standard depleting funds intended for research and innovation. Another reason could be the restrictions imposed by ISO 9001 on the implementation of innovative processes. Nevertheless, almost half of the studies show no impact, either positive or negative, of the ISO 9000 series on product innovation (Manders et al., 2016).

ISO 9001 can have a positive effect on process innovation performance (Terziovski and Guerrero, 2014).

function of standards

MINIMUM QUALITY

Based on data collected through web mining, a 2021 study found a close link between companies seeking ISO/IEC 27001 certification and successful product innovation (although no causal relationship is claimed) (Mirtsch et al., 2021a). The adoption of ISO/IEC 27001 can therefore be considered a preventive innovation in itself, to protect against cyber-attacks *.

* In the same way that vaccination is a preventive innovation to protect against infection (see Rogers, 2002).

Environmental standards fall into the category of minimum-quality standards. The number of ISO 14001 certifications issued has been found to be a strong predictor of a country's environmental patent applications – a proxy for its innovation performance (Lim and Prakash, 2014).

positive impacts of standards on innovation

negative impacts of standards on innovation

Overall, the relevance of International Standards for public policy is poised to increase in the future as the world strives to meet its sustainability challenges, embodied in the United Nations 17 Sustainable Development Goals (SDGs). This will contribute to filling the gap left by the lack of international regulation.

THE RELATIONSHIP BETWEEN STANDARDS, REGULATION & INNOVATION POLICY

In uncertain markets, standards have a more positive impact on innovation efficiency compared to government regulations (Blind et al., 2017).

Standardization is increasingly considered to be an important area of innovation policy and researchers are investigating how policy instruments are linked to standardization, including effects on innovation (Ho and O'Sullivan, 2019). Other important policy instruments are focused on standards development. These include the provision of financial support to innovative research institutes and small and medium-sized companies for their involvement in standardization.

There is a complex interaction between governments' standardization interests, the activities of standards bodies and company incentives for setting de facto industry standards (the case of plugs for electric vehicles is one example). This interaction requires further research to be better understood (Wiegmann et al., 2017).

In mature markets, compulsory regulation proves more effective than standards in promoting innovation efficiency (Blind et al., 2017).

positive impacts of standards on innovation

mixed or inconclusive impacts of standards on innovation

negative impacts of standards on innovation

Challenges for future research

Although the link between standardization and innovation has been widely explored, there are still significant challenges to be tackled in terms of future research. Firstly, most studies assume standards to be exogenous to innovation systems. However, Blind and Gauch (2009) have already presented a comprehensive approach that points to research and innovation being important catalysts for the development of new standards. Hence, these inputs into standards must be taken into consideration when analysing the impacts of standards on innovation.

More recently, Blind and van Laer (2021) revealed a close correlation between research and standardization, on the one hand, and ISO's standardization activities on the other – at least for some countries. This finding complements previous studies showing that the more innovative a company (Wakke et al., 2015) or a country (Blind et al., 2021) is, the greater its participation in standards development. To adequately address these complex interactions, long time series are required to conduct multistage analyses taking this endogeneity into account, for instance by looking first at the development of standards and then their impact on innovation.

In addition to these complex interactions, new forms of collaborative innovation must be given scrutiny. These might include open innovation, but also innovation performed by organizations in their broadest sense, stepping away from focusing only on companies. Here, new topics of user or social innovation should be examined, which often go beyond technical products towards complex process or organizational innovations.

One important new impact dimension of standards is sustainability, which can take many forms as conveyed via the 17 SDGs (e.g. Blind and Hess, 2021). Innovation is not just included in Goal 9 of the SDGs and standards can contribute to realizing many of the other goals as well. In this context, the impact of standards on innovation in emerging economies also needs further attention, as does the complementary relationship between government regulation, on the one hand, and self-regulation through standards on the other. This will mean tackling a relevant, but challenging, new area of research.

From a methodological perspective, it is important to close the data gap between the limited case studies highlighting the impact of standards on specific innovative technologies/products and the large-scale surveys that examine the general function of standards as a knowledge source – and sometimes barrier – for innovation. In particular, the role of individual standards for specific types of innovation, inferred from a representative sample of companies or organizations, requires further investigation. A good starting point is the German Standardisation Panel (**https://www.normungspanel.de/en/**), which performs an annual survey of companies' standardization activities.

Aside from the ISO Survey, which provides data on the number of certifications issued to ISO management system standards, there is still little data on the wider dissemination of standards within companies and other organizations. One recent exception is a study by Mirtsch et al. (2021) that used web mining to gather valid data on all German companies. Furthermore, randomized controlled trials (RCTs) have been introduced, as a form of scientific experiment, to investigate the success of policy measures. It may be worth considering RCTs when examining the impact of standards on innovation; this involves comparing a treatment group of companies that have implemented the standard with a control group in order to understand the impact of many important factors on innovation.

In conclusion, research into the impacts of standards on innovation presents a number of challenges on a theoretical level. For one, it involves considering complex interactions as well as new forms of innovation. But it also requires methodological improvements in order to progress to the next step, i.e. from simply showing correlations to revealing causal relationships. Ultimately, this can only be achieved by gaining access to more precise and representative data on the use of standards, at both national and international levels.

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