This report is part of the Compendium of Evidence on the Effectiveness of Innovation Policy Intervention Project led by the Manchester Institute of Innovation Research (MIoIR), University of Manchester. The project is funded by the National Endowment for Science, Technology and the Arts (NESTA) – an independent body with the mission to make the UK more innovative.

The compendium is organised around 20 innovation policy topics categorised primarily according to their policy objectives. Currently, some of these reports are available.

All reports are available at http://www.innovation-policy.org.uk. Also at this location is an online strategic intelligence tool with an extensive list of references that present evidence for the effectiveness of each particular innovation policy objective. Summaries and download links are provided for key references. These can also be reached by clicking in the references in this document.

Table of Contents

Table of Figures

List of Tables

Executive Summary

In the past, standardisation and standards have often been perceived as a contradiction to innovation. This report provide conceptual arguments and empirical evidence that standardization as such and standards can be used as to promote innovation especially in three different areas. After a brief section on the general economic functions of standards, the relationship between research and standardisation is examined by first showing both standardization as a technology transfer channel and standards as enablers and facilitators for research. The second area focuses on the difficult but promising issue of transferring intellectual property rights (IPR) into standards, and shows how this can be beneficial both for IPR holders and standards implementers. The third newly emerging field concerns the role of standards and standardization in procurement processes, which are more and more forced to address and promote innovation. In the final chapter, the results are summarised and recommendations for policy makers are derived.

.

1 Introduction

Standards form the basis of our professional and private life and innovation is the major source of growth and welfare for our economies. The challenge both for decision makers in industry and policy is an effective and efficient use of standardization also to promote innovation, especially since the traditional view has always been that standards and innovation contradict each other. This perception had some negative implications for the integration of standardization both in companies' innovation processes and in a comprehensive innovation policy. Here, we observed in the past a strong focus on public funding of research and development and on intellectual property rights (IPR) as instruments of innovation policy. However, economic impacts of research results and IPR can only be realised through their successful transfer into innovative products and processes. Unfortunately standardization has not yet been used in a comprehensive sense as effective and efficient technology transfer channel. In addition, standards can play an effective leveraging and diffusion mechanism for IPR. However, this might also create possible conflicts between the actors involved. Standardization is also a platform used by researchers and other actors in the innovation process, and standards are important elements in the framework conditions for research, development and innovation. Finally, user driven innovation strategies and consequently demand driven innovation policies have recently been promoted, but standardization as a tool to coordinate the preferences and actors of the demand side has not been considered.

In sum, there is a large potential for standards and standardization to promote innovation for policy makers. However, only recently have we observed some policy initiatives, such as the Lead Market Initiative of the European Commission and some national innovation strategies now focusing on standardization as a crucial innovation policy instrument.

This report will give an overview of the function of standardization and standards to promote innovation from a conceptual view in the second chapter, which is complemented by an overview of the existing, but limited empirical evidence in the third chapter. The report is concluded by a summary and a set of recommendations how policy makers should use standardization and standards in shaping future innovation policies.

1.1 Definitions

Facing a controversial discussion about the definition of standardization and standards (De Vries 1997), we make use of the official definition of the International Organization for Standardization (ISO) and the International Electrotechnical Commission of standardisation (IEC) as producing documents "by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" (ISO/IEC Guide 2004).

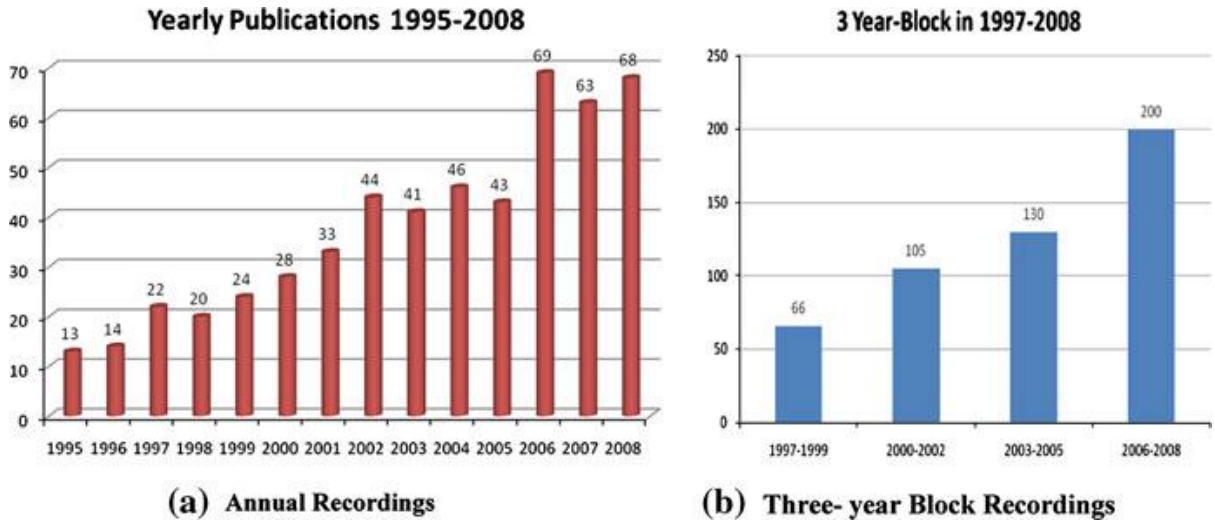
The key point is that standardization is a voluntary process for the development of technical, but more and more also other types of specifications based on consensus amongst the interested parties themselves: industry in first place, but also a variety of users, interest groups and public authorities. Standards, as result of standardization, have the following characteristics. They are made available to the public free of charge or for a mostly cost covering fee. Implementation is in general free of charge. Only in some cases they are subject to

the payment of compensation to owners of related IPR, mostly patents (Blind et al. 2011). Finally, the usage of standards remains voluntary, although harmonised European Standards are part of the regulatory framework within the context of the so called new approach (www.newapproach.org).[1] Formal standardisation includes the following organisations. Standardisation bodies such as British Standards Institution (BSI) are the institutions responsible at the national level. At the European level, the European Standards Organisations CEN, CENELEC and ETSI have been established for the general, the electrotechnical and the telecommunication related standardisation areas. Correspondingly, the international standards organisations, ISO, IEC and ITU, share the standardisation work at the international level. In general, I will focus on standardisation in these formal standardisation organisations and will not address rather informal standardisation consortia and fora, which are especially specialised in the information and communication technology (Blind and Gauch 2009).

1.2 Types of standards and their effects on innovation

In his update of his report published in 2000, Swann (2010) stated that there is still only a rather limited number of publications and especially limited empirical research evidence on the interrelationship between innovation and standardization. However, he concedes that the literature has made some steps forward in the last ten years. This is underlined by the recent literature review by Choi et al. (2011) on standardization and innovation covering the period between 1995 and 2008, which shows a continually increasing number of publications.[2]

Figure 1: Research trends for standardization and innovation for 1995–2008 (Choi et al. 2011, p. 263)



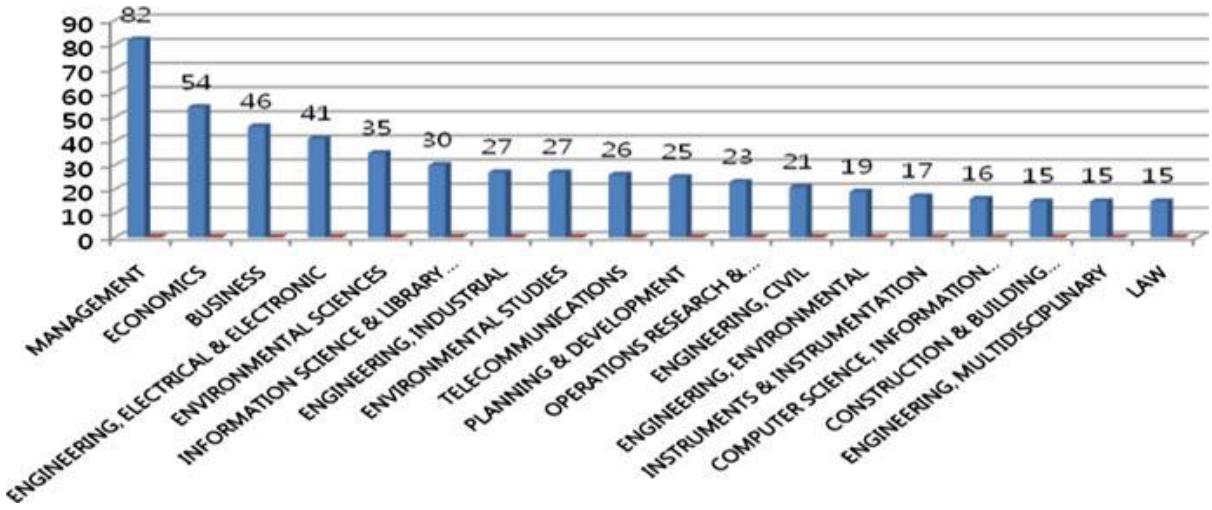
The publications have clearly their focus in the management, business and economics area followed by some specific network technologies or papers on environmental standards.

---

1 The link between voluntary standards and governmental regulations is quite different in other regions of the world. In Japan, but also China, the standardization activities are under the roof of ministries, which leads to standards being equivalent obligatory like technical regulations. In the United States, technical standards are produced by numerous industry associations and are in general not linked to the regulatory framework.

2 The search was based on an extensive number of keywords in the scientific domains of management, environment, economics, computer and information systems, chemistry and telecommunication and electro-technology.

Figure 2: Major subject domains of the publications on innovation and standardization



Choi et al. 2011, p. 265

A clustering of the papers revealed the following list of clusters displaying different, but rather heterogeneous dimensions of the interrelationship between standardization and innovation.[3]

Table 1: Exploratory taxonomy for literature on standardization and innovation [4]

Clusters	Descriptions
Inter-relationship of Standardization and Innovation	**Interrelationship between standardization and innovation; Implementation of standardization as an innovation tool; Policy perspective of technological standards and innovation**
Diffusion/Transfer of Tech/Knowledge	**Standards adoption, and innovation diffusion (model, factor, network); Standards and knowledge transfer**
Regulation/Integration	**Standardization as an integration tool; Regulatory standards and innovation in technology-based industry**
IPR/Patent/Law	**Standards and IPR in a competitive market; Patent, standards, and legal issues**
Impact and Competitive Strategy	**Impact of technology standards in market competition; Standards and structure and modeling; Standardization as a business competition strategy**
Business Performance	**Business development, performance, standards; Standardization for innovation and technological performance**
Technology and Product	**Specific technology development, standards, and innovation; Technology and product design and standards and innovation**
Quality and Management System	**Quality assurance and management system standards for innovation; Environmental management systems standards**
Service	**Role of standards in service innovation; Service, network, and communication standards**

[3] Recently, Narayanan and Chen (2012) present an analysis of 89 papers published in top management journals on technical standards in general. On the macro level, the positive impact on the diffusion of innovation has been confirmed, whereas on the company level they mention only that compatibility is functionally critical when innovative firms desire to shift the locus of standards from an existing new technological system to a new one.

[4] based on Choi et al. 2011, p. 271

In contrast to this data driven and little intuitive taxonomy, Swann (2000) conducted a first comprehensive survey on the existing literature on standards and standardization. Related to innovation, he identified the following factors:

a) Standardization helps to build focus, cohesion and critical mass in the emerging stages of technologies and markets

b) Standards for measurements and tests help innovative companies to demonstrate to the customer that their innovative products possess the features they claim to have, but also acceptable levels of risks for health, safety and the environment

c) Standards codify and diffuse state of the art in science and technology and best practice

d) Open standardization processes and standards enable a competition between and within technologies and contribute therefore to innovation-led growth.

Overall, standardization generates standards, which are an essential component of companies' infrastructure. Consequently, they enable innovation, but also try to hinder undesirable outcomes (see references in Swann (2000)). A crucial question is whether standardization overall constrains or enables innovation, which was also addressed in his updated survey (Swann 2010). The perception of standardization as infrastructure combines both impacts, because any type of infrastructure generates opportunities for its users, but also does not allow some options to be realised, i.e. standards reduce the transaction costs and facilitate trade, especially of complex products and across borders. Furthermore, the infrastructure standards build provides the basis for subsequent generations of innovation. By limiting the variety of all available options standards help to focus on specific technologies and consequently promote the development of critical masses, which increases the credibility especially in new technologies attracting further investments and the development of complementary technologies. When technologies have been established, standards allow the exploitation of economies of scale, which generates profits both as incentives to innovate and to re-appropriate the investments into innovation. Innovative technologies and products contain often a higher level of risk for health, safety and the environment, which endanger their acceptance among private and commercial users, but also policy makers. Thus, standards can provide some contribution to the trust into innovative technologies and products by reducing the various types of risks both for the users, but also for society. In cases of strong network externalities economic models help to explain why radical innovations are sometimes considerably delayed by the presence of standards (e.g. Arthur 1989 and Katz and Shapiro 1992). However, standards are not only contributing to lock-ins into old technologies becoming inferior over time, but can also be shaped to avoid these lock-ins, e.g. by designing appropriate interfaces between old and new technologies allowing their simultaneous use or ensuring their compatibility.

Based on the various literature reviews, Table 1 provides a condensed overview of four types of standards and their positive and negative impacts on innovation. [5]

[5] Guasch et al. (2007) introduce a second dimension related to innovation, i.e. the exploitation of network effects; innovative and productive efficiency, reduction of imperfect information and innovation diffusion. Leech and Scott (2011) have applied this approach to so called documentary standards based on Tassey (2000), who introduced standardization as infratechnology. However, this approach does not provide further insights for the purpose of this overview.

Table 2: Types of Standards and their Effects on Innovation[6]

	Positive Effects on Innovation	Negative Effects on Innovation
Compatibility / Interoperability	• Network externalities • Avoiding lock-in old technologies • Increasing variety of system products • Efficiency in supply chains	• Monopoly power • Lock in in old technologies in case of strong network externalities
Minimum Quality/ Safety	• Avoiding adverse selection • Creating trust • Reducing transaction costs	• Raising rival's costs
Variety Reduction	• Economies of scale • Critical mass in emerging technologies and industries	• Reducing choice • Market concentration • Premature selection of technologies
Information	• Providing codified knowledge	

2 Function of standardization and standards in the context of specific innovation activities

After giving an overview of the general innovation promoting and hindering impacts of standards, the role of standardization and standards to promote innovation, but not necessarily to generate innovations themselves in the narrow sense, will be elaborated in this section in three specific areas, which are most important for the traditional instruments of innovation policy.[7] At first, we have selected research as a supply side oriented innovation activity, to elaborate the role of standards in research and as a transfer channel for research results. Secondly, we elaborate on the interaction between standards and intellectual property rights in order to identify possible leverage effects, but also some risks. Finally, standards not only reduce the time to market inventions and innovative technologies, but in the first place allow their marketing, e.g. by creating critical masses or collecting the support of all relevant stakeholders. They also help to accelerate the diffusion of innovations.

2.1 Research and standardization

Research and development (R&D) is the focus of most innovation policies, e.g. confirmed by the target to spend 3% of GDP in the European Union in the year 2020 and by the surge for R&D tax credits Köhler et al. 2012). However, the commercial success and economic impact of R&D results will only be realised by a successful transfer of these results into innovative products and processes. Consequently, manifold support mechanisms for technology transfer have been implemented, but standardization as an instrument of technology transfer has only recently been recognised, at EU level in the context of the upcoming Horizon 2020 programme or - a few years earlier, - ago in the context of the German HighTech Strategy.

---

6 Source: modifying Blind 2004 based on Swann 2000

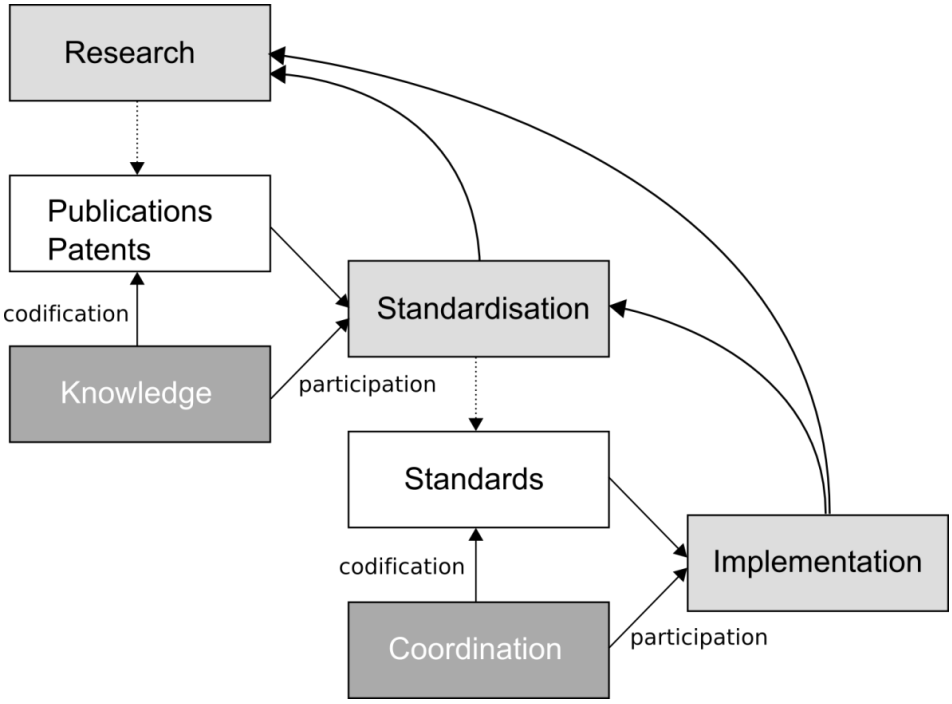
7 This section draws on Blind (2009), but has been shortened and updated.

Taking Bozeman's (2000) conceptual transfer model as a basis Blind and Gauch (2009) integrate standardization as a transfer channel and consequently standards as the transfer object. More precisely, standards are a knowledge and technology transfer channel for knowledge integrated within a consensus process. The selection and prioritisation of knowledge and technologies leads to the bundling of resources and avoids fragmentation. In addition, this is accessible for all actors in industry, research institutes, the public sector and society.

In relation to public research programmes, economic efficiency is realised if publicly funded R&D results become public goods via standards. These standards, in contrast to patents, are accessible to everybody at low cost and are more likely to be broadly implemented because all (interested) stakeholders have reached consensus on the specifications they contain. In addition, the standardization process as such is a knowledge sharing and knowledge production process, because it is a common platform for actors with heterogeneous backgrounds, capacities and knowledge, i.e. research, industry, public administration, social interest groups, e.g. consumers. Besides the codification of knowledge in standards, an exchange and even the production of tacit knowledge takes place during the standardization process. Finally, inputs from heterogeneous sources, especially of knowledge from implementers of standardized technologies and consumers of standardized final products. Therefore, taking all these aspects together, standardization provides the chance for the practical implementation of research results in innovative technologies, products and services.

Two critical aspects of such a transfer approach have to be mentioned. First, the incentives for researchers and their organization to join standardization processes are limited, because of opportunity costs, like less time for writing scientific papers and being restricted in commercialising the research results (see also next section). Second, standardization processes are time consuming, which may create also some delay in the transfer process. However, patenting processes are often longer than the average standardization process of three years (e.g. see Berger et al. 2012).

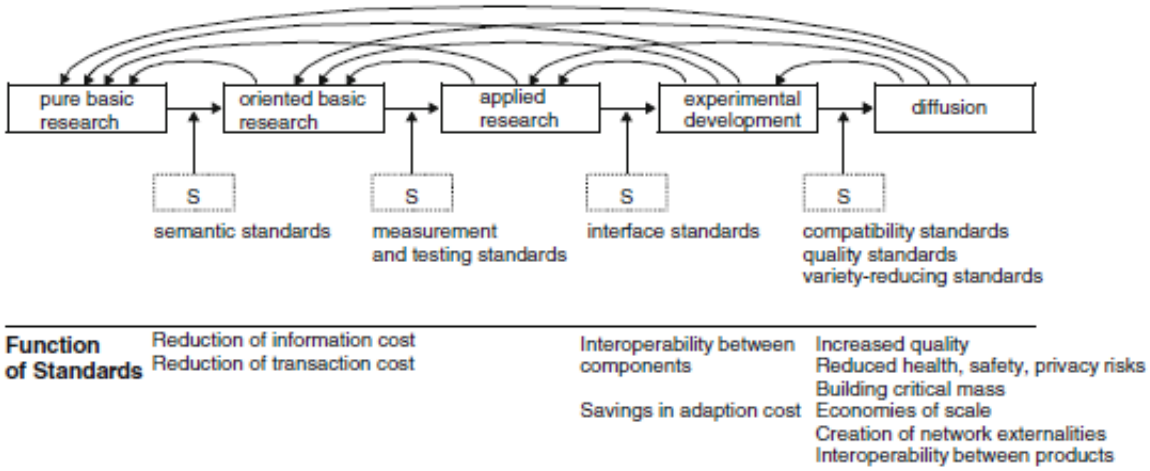
Figure 3: Research and standardisation in a simple technology transfer model[8]



In addition to the transfer of knowledge from research to standardization, standards themselves can serve as framework conditions for the next generation of research. This is especially the case for terminology and classification standards in the area of basic research. Metrology, measurement and testing standards are more relevant for applied research. Quality, health and safety standards are crucial for market introduction by restricting possible risks of innovative technologies and products. Finally, compatibility standards can promote the diffusion of technologies and products especially in network industries. Across all these dimensions, standards can supplement or complement governmental regulations. For example, in early stages of emerging research and technology fields, self-regulation via standardization allows stakeholders to set flexible framework conditions, which can later be transferred into governmental regulations. In order to exploit these various potentials of standards for research, they have to be developed in time, which requires systematic standardization foresights (Goluchowicz and Blind 2011).

8 Source Blind and Gauch, 2009, p. 324

Figure 4: Various roles of different types of standards in the innovation process[9]



2.2 IPR and standardization

Research results are increasingly protected by intellectual property rights (IPR), especially patents, driven by policies and strategic motives to patent (Blind et al. 2006). In addition, IPR institutions such as patent offices, have incentives to award IPR also in new fields such as software. Consequently, there are more discussions regarding the quality of IPR, e.g. patent thickets, patent trolls etc. and as a result we face an enhanced interaction between IPR, especially patents and standards (Rysman and Simcoe 2008, Simcoe et al. 2009, Blind et al. 2011).

The integration of IPR, especially patents, into standards, which is possible during the overlapping phase of patent application and standardization (see Berger et al. 2012) generates a series of benefits both for the owner and for those interested in implementing these standards, but also some challenges.

First the incentive function allows rights holders to leverage their temporary monopoly generated by the awarded IPR via their integration into standards, which generates additional incentives for investment in R&D. The downside of the combination of IPR and standards is the expansion and cementation of the temporary into a permanent monopoly, which restricts not only competition, but also innovation, because it becomes incontestable. A second, indirect incentive from the combination of IPR and standards emerges from the constellation that often technologies, products and services are based on platform standards, which are often open and IPR free. This creates by indirect network effects generated by standardized platform technologies additional incentives for investment in R&D to generate proprietary technologies and products. In contrast to the mostly incontestable market position of companies owning proprietary standards via IPR, there is in general still a competition between the various complementary technologies and products.

A direct positive implication of the integration of IPR, especially patents, is the pooling of patents into standards (see Bekkers et al. 2012). This reduces transaction costs both for the patent owners and the standard implementers, but also generates additional licensing revenues

[9] Blind & Gauch, 2009, p. 325

for the former due to the diffusion effects of standards and reduces licensing costs for the latter. Finally, patent pools avoid the so-called double marginalization and therefore reduce the prices for the whole bundle of licensing necessary for the implementation of the standards. This does not only further increase the incentives, but also promotes the diffusion of the standard and consequently also of the incorporated IPR.

Besides the numerous potential economic benefits of IPR in standards, we also have to consider the potential costs for innovation. The combination of IPR and standard-based network externalities may lead to monopolies lasting longer than the maximum length of patent protection, which creates inefficiencies e. g. by higher prices and market structures with a low level of competition. In addition, such dominant positions may also promote lock-ins in the long term into inferior outdated standards. In contrast to the tendency towards monopolisation by the integration of IPR into standards, this rather strong incentive may generate fierce standard wars with wasting of resources due to overinvestment and duplication of efforts. These potential significantly negative effects of integration IPR into standards have to be taken into account when considering the benefits.

The interaction between IPR and standards could lead to possible conflicts between the two institutions and as a consequence could result in more costs. The implementation of a standard can lead to an unintended infringement of IPR not known to be part of the standard. Such an infringement can also be caused by strategic ex post disclosure of IPR by submarine patents after completion of standardisation processes. Finally, if we assume no infringements, the licensing of IPR integrated into patents needs to be considered. IPR and especially patents integrated into formal standards released by standardization bodies have to be licensed by the owner according to Fair Reasonable and Non-Discriminatory (FRAND) conditions. However, it remains rather vague how FRAND is defined in practice. Finally, even if FRAND leads to reasonable licensing fees in the case of the single patent, the accumulation of licensing fees for IPR by different owners may generate licensing costs. Consequently, those interested in implementing the standard would incur higher costs.

2.3 Standards in public procurement

From the demand side, standardization can help to create critical mass and allow to start the exploitation of economies of scale in the formative stages of a market, e.g. standards can focus demand for innovations that might otherwise be spread over many technical solutions and therefore might lead to a high fragmentation and not sufficient critical masses. Especially in network industries, such as ICTs, standards can facilitate the formation of an installed baseof users. In this connection, standards ease the emergence of technological platforms based on independently supplied, but interoperable components due common technical standards. Successful platforms based on open standards are the Internet and the cellular telephone, are based on open standards. Open standardization processes allow that standards reflect user needs and therefore promote the diffusion of new products by early adopters. Finally, standards can be used like regulations to set minimum requirements for environmental, health and safety aspects in order to reduce information asymmetries and to promote trust in innovative products.

Table 3: Types of Standards and their Effects on Innovation[10]

	Different Types of Standards and their Major Demand-side Effects for Innovation			
	Generation of Network Effects	Generation of Economies of Scale	Reduction of Information Asymmetries	Reducing Uncertainty and Risk
Compatibility / Interoperability	**X**			
Minimum Quality/ Safety				**X**
Variety Reduction		**X**		
Information			**X**	

Using these various demand-focused functions of standardization and standards, standards can also be used by the public sector in the context of public procurement, notably in tender specifications. The adoption of challenging and innovative standards in procurement schemes (e.g. fuel-efficient tyres in Japan) can for instance be used by governments to diffuse innovations to the private sector.

Based on the insights on technology push and demand pull as drivers for successful innovations, coordination between the two forces is necessary. Furthermore the innovation system approach emphasises the relevance of integrating the demand side in successful innovation processes (Lundvall 1988, Edler 2013). As a result, we have recently observed an increased focus on demand driven innovation also in innovation policy (OECD 2011a, Izsak and Edler 2011). The instruments of demand policy are direct public funding of demand for innovative products, subsidising private demand, public procurement, regulation and eventually standardization. So far we have seen little focus on standardisation and no systematic use or coordination of the various instruments at all.

Besides the use of public procurement to push innovation, there are several positive impacts of innovation for public procurement. First, innovations can improve the quality of public services and public infrastructures, which may lead to a high customer, i.e. citizen, satisfaction. In addition, such improvements in public services represent an advantage in the intensified competition between regions. Second, innovations may lower the costs over the whole life cycle of a technology, e.g. by lower energy, maintenance and repair costs. However, innovations also have negative impacts for public procurers. First, the purchasing price might be higher due to new features or improved product characteristics. Secondly, innovative technologies, products and services bear higher risks for the user, but also e.g. for the environment, and can increase maintenance costs due to less experience. Finally, specific innovations can be made only by a small number of suppliers or even a single company.

Standards can help to support the innovation promoting function of public procurement by the following mechanisms (Blind 2008). First, the implementation of standards in innovative products can reduce production costs and therefore the price to be paid by public procurers and the life cycle costs, e.g. by lower expenditures for repair and maintenance. Secondly, standards

[10] Source: based on OECD 2011b

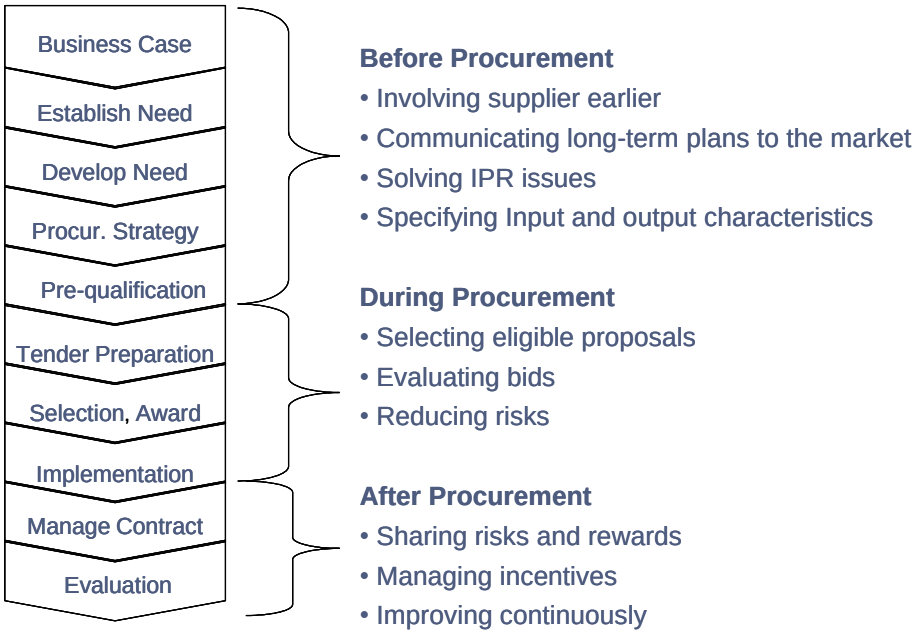
can secure the interoperability of the purchased innovation with the existing infrastructure, which also includes the transition from old to new technologies, e.g. by lower costs for gateways or converters. Thirdly, standards push the competition and therefore the innovative pressure among competitors for public tenders. Fourthly, the use of standards reduces the risk of lock-in to a specific supplier. Fifth, there is a direct innovation effect for companies through the implementation of newly released standards referenced in tenders. Sixth, standards reduce the risks related to costs, health, the environment and safety for the public procurer and consequently create a leeway for the procurement of products and services with innovative characteristics. Finally, the use of standards in public procurement facilitates positive spill-over on innovation promoting procurement processes in the private sector. In summary, using standards in public procurement results in a long list of positive innovation promoting impacts. However, there are challenges and risks associated with standards in public procurement as well. The decision for a specific standard requires a high level of knowledge both about the technological landscape and its future development and about the market situation. Ghosh (2005) argues that the combination of patents, standards and public procurement can lead to a triple dividend especially for dominant market players, which has to considered and restricted in order to avoid the development of incontestable monopolies.

Since the public procurement process is rather comprehensive, standards come into play at various stages. Before procurement, the supplier might be in discussion about the general options related to the upcoming procurement process, which should also include an analysis of the standards that might be appropriate. Consequently, the communication of long-term plans to the market should also include the standards that could be referenced. The strategic referencing of standards can also be used to solve IPR issues ex ante. Eventually standards are crucial for the specification of both the input, e.g. requiring specific qualification standards, and of the output, e.g. by asking for specific quality standards.

During the core procurement process, the selection of eligible proposals can be based on compliance to the required basic standards. The specific evaluation of the bids can be facilitated by considering standards, possibly with different performance levels. Eventually, possible deviations from the agreed performance of the delivered products or services can more easily be identified by benchmarking them to the referenced standards and possible conflicts can also be settled in court more easily with the help of standards.

After the completion of the procurement process, standards can reduce the transaction costs caused by liability cases by again identifying deviations from the agreed performance using standards as references. The same is true for rewarding outperforming contractors based on references to ex ante agreed standards. In case of long term contracts, the quality of the delivered products and services has to develop with the progress in technology, which can more easily be monitored by taking into account newly released standards.

Figure 5: Role of standards in public procurement[11]



3 Empirical Evidence

The empirical evidence about the economic impacts of standardization and standards, which is emerging, but still quite limited, will be presented in the first section, followed by the overview of some studies on the relationship especially between standardization and innovation. In the last section on the empirical evidence, we give insights into the first very limited evidences on the specific interaction between standardization and research, IPR and public procurement.

3.1 The general economic impact of standards

The role of standards in the diffusion of technical knowledge and their resulting contribution to economic growth has been demonstrated in various empirical studies. For the time period between 1961 and 1996 calculations showed that the information contained in standards and technical rules was responsible for 1 % of Germany's gross national product (DIN 2000). This German study on the micro- and macroeconomic benefits of standardization was used as a model for several other national studies. It was followed by further analyses which not only used similar methodological approaches and covered similar time frames, but also led to comparable results. As a whole, all of the national studies demonstrate that standards have a positive influence on economic growth due to the resulting improved diffusion of knowledge. The contribution of standards to the growth rate in each country is equivalent to 0.9 % in Germany, 0.8 % in France and Australia, 0.3 % in the UK and 0.2 % in Canada. The update of the German study aimed to recalculate the economic benefits of standardization on the basis of current data, because not only the time series available after reunification has been expanded, but standardization has also changed in many ways. Today about 80 % of all standards published in Germany are of European or international origin. The current study also makes use

[11] Source: Blind 2009 based on Office of Government Commerce 2004

of new knowledge regarding data structure. However, the contribution of the stock of standards to growth remains quite stable despite reduced overall growth.

Table 3: National studies of the effects of standards on economic growth[12]

Country	Publisher	Time frame	Growth rate of GDP	Contribution of standards
Germany	DIN (2000)	1960-1990	3.3%	0.9%
Germany	DIN (2011)	1992-2006	1.1%	0.8%
France	AFNOR (2009)	1950-2007	3.4%	0.8%
United Kingdom	DTI (2005)	1948-2002	2.5%	0.3%
Canada	Standards Council of Canada (2007)	1981-2004	2.7%	0.2%
Australia	Standards Australia (2006)	1962-2003	3.6%	0.8%

Since standards play very different roles depending on the characteristics of technologies, e.g. based on network externalities, and market structures, e.g. heavily fragmented or strongly concentrated, industry specific studies are more adequate. Consequently, Blind and Jungmittag (2008) are able to show that the stocks of standards are a stronger growth driver for more mature, i.e. less R&D intensive, sectors with the exception of the industries based on electrotechnology and information technology.

Parallel to the macroeconomic and industry-specific approaches to assess the impacts of standardization, numerous case studies focusing on specific standardization processes and standards have been conducted. Based on quite systematic approaches, two initiatives have to be mentioned.[13] First, the ISO (2011, 2012) performed a series of studies in numerous companies operating in a variety of business sectors in ten countries. The studies are based on Porter's value chain. Overall the studies showed that implementing standards can provide economic benefits from between 0.5 % and 4 % of their annual sales revenues. However, the approach does not take explicitly the impact on innovation into account. Second, the National Institute of Standards and Technology has a longer tradition of impact assessments of its standardization activities, e.g. Brunnermeier and Martin (1999), Leech and Chinworth (2001) and Gallaher et al. (2002) and recently Leech (2012b). However, these studies do not address explicitly innovation as an impact dimension. Recent exceptions are the studies by Leech (2012a), which takes at least the interaction between standardization and the innovation systems into account, and Leech and Scott (2011), who show, how innovation was fostered from the close collaboration of industry and the National Institute of Standards and Technology (NIST), solving difficult technical and commercial problems using NIST's unique resources in standards development.

12 Source: update of overview in DIN 2011

13 An overview of case studies mostly performed within academia can be found in Swann (2000).

3.2 The impact of standards on innovation

Whereas the influence of innovation on standardization has been confirmed at the macroeconomic (Blind 2002) and the company level (Blind 2006a, Blind and Mangelsdorf 2013), the impacts of standards on innovation has been investigated only to a limited extend starting with Blind (2004).

Using the methodological approach of matching standards and patent data developed by Blind (2004), Konrad and Zloczysti (2010) replicate and update his analysis finding again a positive correlation of patenting and standardization activities in German industries. However, a causal relationship was not tested, whereas Blind (2004) finds at least a weak influence of the stock of standards on patents applying Granger-causality tests.

Besides the few indicator-based studies, numerous studies rely on company survey data. Swann and Lambert (2010) uses data from the British Community Innovation Survey to examine the question: "Do standards enable or constrain innovation?" For the analysis the responses of companies to the following questions are used:

a) How important to your enterprise's innovation activities is the following information source: technical, industry or service standards?

b) How important a constraint to your innovation activities was: the need to meet UK/EU regulations?

The results confirm – as previous analysis published in DTI (2005) – that standards enable and constrain innovation, i.e. the answers to these two questions are positively correlated in the sense that amongst the 60% of companies who said that standards were a source of information for innovation activities, the majority also confirmed that regulations – and not standards[14] – were a constraint on their innovation activities. Simultaneously, amongst those companies for which standards were not a source of information for their innovation activities, regulations were not perceived as a constraint on their innovation activities. In addition, Swann and Lambert (2010) also find that those CIS respondents who say that standards inform and constrain, are also those who are more successful in many of the CIS measures of innovation, i.e. those that say standards inform their innovation are – as expected – more innovative than those who say standards do not inform. However, unexpectedly companies, which are constrained by regulations, are more innovative than those which are not constrained.

Swann and Lambert (2010) offer two further interpretations of these results. First, they note – as argued above – that standards have several different purposes and/or aspects. Some of these are primarily informative (e.g. codified knowledge) while some are primarily constraining (health and safety). But any one standard may contain several of these aspects and purposes. Taken as a group, the set of standards relevant to any one company will contain a mix of information and constraints. To presume that standards will either be informative or constraining is to create a false antithesis: any one standard may have both of these effects at the same time, and any group of standards is highly likely to contain both. Second, they observe that those firms which use standards as an information source for innovation and which are

[14] This is a problematic inaccuracy of the analysis, because Blind (2006b) shows that standards are not perceived in the same way as regulations as obstacles to innovation.

constrained in their innovation activities by regulations are very innovative. Obviously, they are efficient in squeezing information from standards and successful in overcoming these constraints by regulations.

In a further step, King (2006) investigated to what extent the informing and constraining role of standards depended on the size and condition (average age) of the standards stock. The first analysis published in DTI (2005) finds that the information content of the stock of standards increases with the number of available standards and, up to a point, also increases with the median age of this stock. However, beyond a certain point, an increasingly elderly stock of standards faces a depreciation of its information content. A similar non-linear effect is found in the constraining role of standards: it seems likely that both rather old and rather new standards constrain innovation – the first because it locks the innovator into legacy systems and the latter because it challenges the innovator. King (2006) carried out a very thorough exploration of these hypotheses using more recent data and applying a series of extensions and robustness checks on the above results. Eventually, he found that some of the postulated nonlinearities, i.e. having a positive influence of standards on innovation only up to a certain number and to a specific age, are not robust.

In a most recent study based on various waves of the British Community Innovation Survey Frenz and Lambert (2012) conduct factor analyses including also standards as a source of information for innovation. They find that this source loads together with other external information sources such as the public knowledge base, publications and other businesses. However, their findings challenge the interpretation by Swann and Lambert (2010), because the use of standards shows low correlations with other modes of innovation. Especially, they are surprised about low correlation of standards with process modernizing. Consequently, they interpret this as an indication that using standards is a relatively specialised means of using external codified information in a firm's innovation strategy.

Mangiarotti and Riillo (2010) use the Community Innovation Survey for Luxembourg complemented by information on ISO9000 certificates to test the ambivalent relationship between standardization and innovation. Their main finding is a positive influence of ISO9000 certification on the probability of innovation, when organizational and marketing innovation are included into the definition of an innovative company. Applying more restrictive definitions of innovation, ISO9000 certification promotes the likelihood of companies to introduce technical innovation in the manufacturing sector, but only non-technical. i.e. organizational and marketing innovations in the service sector.

Blind (2006a) find a positive influence of companies' R&D-intensity up to a certain level, i.e. a U-shape, on their likelihood to join standardization processes based on survey data covering the whole German industry, which is confirmed by Blind and Mangelsdorf (2013) for the German electrotechnical and machinery industry. Finally, Blind et al. (2011) are able to match data of the Dutch innovation survey with companies active in the Dutch standardization institute NEN and conduct similar analyses with a focus on services. Whereas they find a linear relationship between service companies' R&D intensity and their likelihood of being involved in standardization, there is obviously an inverted U-shape for the influence of companies' turnover with market innovations on their inclination to join standardization processes. Although these studies explain the participation in standardization by various innovation measures, they claim not a causal relationship between R&D or innovation activities and standardization. Therefore,

these findings can also be referred to indicate a general positive relationship between innovation and standardization, which could also be caused by standardization.

On a qualitative level, the study of Blind et al. (2010b) on the impact of international ICT standards based on quantified expert opinions from three standardization organizations shows that ICT standards have a positive impact on innovation, especially on product variety, the degree and speed of adoption of new products and services. A similar approach focusing on the role of standardization in nanotechnology addressing both companies and research institutes has been performed by Blind and Gauch (2009). The responses of the experts reveal that the main motivations to join standardization in this emerging technology are finding agreed rules leading to interoperability, compatibility, common terminology etc., a better dissemination, but also commercialization of research results by standardization, eventually also a high legal security in new fields of science and technology (e.g. reducing risks of liability) and better links and collaboration with other researchers and developers.

There are further case studies on the benefits of standardization on innovation. As an example, the study by Aphrodite (2011) on biometrics standards has proved that the use of standards had accelerated progress on biometrics programmes, such as that run by the Identity and Passport Service, and had future-proofed the technology. In addition, the standards allowed the UK government a more efficient and cost-effective procurement. Finally, all industry players, including some SMEs, have now the chance to compete on the same leveled playing field in the market. Another recent case study by Michel (2012) investigated the role of standards in the Dutch EV charging infrastructure for innovation. It has been identified that the focus on avoidance of technological lock-ins and on enabling competition has been supportive for innovation. Especially, the compatibility between different charging stations and EV service providers was seen as necessary to execute a market model which is open to multitude of companies being in competition with each other. Finally, flexibility in the standards, by describing only performances (see also OECD 2011b, which discuss mainly performance-based regulations and not – as claimed in the report – standards), was seen as beneficial for innovation in charging infrastructure, but was limited to compatibility standards for communication. Stability of the Dutch EV charging infrastructure was created by choosing a fixed design for the socket of charging stations and by creating a roaming model for EV service providers by convention. This example underlines the interplay between flexibility and restricting infrastructures in order to promote innovation. In a case study on the related smart grid technology NIST (2010) underlines the mediating role of standardization as a platform in the development of complex emerging technologies.

Overall, the various studies on the macroeconomic level, and the microeconomic ones based on company or expert surveys and on specific case studies are able to show the positive correlation or the complementarity between standards and innovation, but not necessarily the causality of standardization promoting innovation. For such complex analyses controlling for the endogeneity of standardization, i.e. the approved influence of innovation, not only time series of data, but additional complementary data to construct instruments is necessary. However, this type of data is currently not available, but partly under construction.

3.3 Research and standardization

The role of standardization and standards has been investigated by the FP6 project "Integrating Research and Standardisation" in a comprehensive way for the first time. As already mentioned, Blind and Gauch (2009) identified the motivations of researchers employed by public or private research institutes, but also by companies, to be involved in standardization. Furthermore, their conceptual model of the role of standards for the various stages in the research and innovation process can be confirmed not only for the case of nanotechnology, but for all areas of research (INTEREST 2005). The special role of standards for research in ICT, even in basic research, has been confirmed by Gauch (2006).

The role of standardization and standards for research has been meanwhile acknowledged in various national innovation policies. Recently, O'Sullivan and Brévignon-Dodin (2012) analyze some international approaches to the support for standardization in emerging technologies within the national innovation systems of the United States and Germany. However, the report reviews only existing analyses from especially from standards development practitioners and policy makers. Furthermore, case studies on regenerative medicine (tissue engineering), smart grid, additive manufacturing and synthetic biology present the broad spectrum of standardization patterns and activities in emerging technologies. Unfortunately, neither specific impacts nor generalizable empirical evidence is presented.[15]

3.4 IPR and standardization

The interaction between IPR and standardization, which has been analysed on the company level (e.g. Blind and Thumm (2004)), has innovation enhancing impacts, i.e. on incentives to invest in innovation, on the selection and coordination of technologies and eventually on their diffusion. Some of them have been empirically approved and will be presented in this section.

As explained above, the option to integrate IPR, especially patents creates at first additional incentives to invest in R&D. This incentive impact is difficult to identify and to measure. However, recently Baron et al. (2011) could at least confirm for several hundreds of standards in the area of information and communication technology that into those standards including patents the involved stakeholders have been invested much more measured by the number of revisions and standards' lifetime.

At second, standardization is about the decision for a specific technological specification among a set of various options. Rysman and Simcoe (2008) provide empirical evidence that standard setting organisations select successfully patent protected technologies, which are superior to other available technologies. Furthermore, the selection of these technologies promotes their success especially in the long run measured by the citations the patents receive.

[15] Meanwhile, the INS Program (Innovation with Norms and Standards) funded by the German Ministry of Economic Affairs and Technology has been evaluated. Unfortunately, the evaluation report has not been published. Furthermore, long-term impacts on innovation cannot been identified yet, because the program has only been started in 2006. The transfer-focused parallel program TNS Program (Transfer of R&D results through Standardisation) has only been started 2010 and not at all been evaluated yet.

Since more and more technologies, often protected by patents, have to be integrated not only in the product development stage, but already in the standardization process, standards containing patents are not always, but often connected to patent pools. Therefore, we can also rely on the – again restricted – empirical evidence on the innovation impacts of patent pools. The kind of coordination via patent pools has already been addressed by Shapiro (2001) as a solution to navigate through thickets of overlapping and complementary patents. Lerner and Tirole (2004) provide an economic justification for the assumption that patent pools are in general welfare-enhancing. The more scarce empirical literature analyzes which rules are adopted by what kind of pools (Lerner et al., 2007) and how the rules of patent pools determine firms' decision to join (Layne-Farrar and Lerner, 2011). More innovation relevant studies show that there are ambivalent impacts of patent pools on subsequent patenting and technological progress (Lampe and Moser (2009, 2011, 2012) for historical patent pools, Joshi and Nerkar (2011) for a recent case). However, Delcamp (2011) studies the impact of pools upon the efficiency of patent enforcement and finds that the introduction in a pool fosters the patents' enforcement. Obviously, the exchange between the pool members increases the likelihood that the infringement is detected by the patent owner. Furthermore, introducing patents in patent pools reduces the uncertainty on the patent essentiality and facilitates the dispute resolution by settlement.

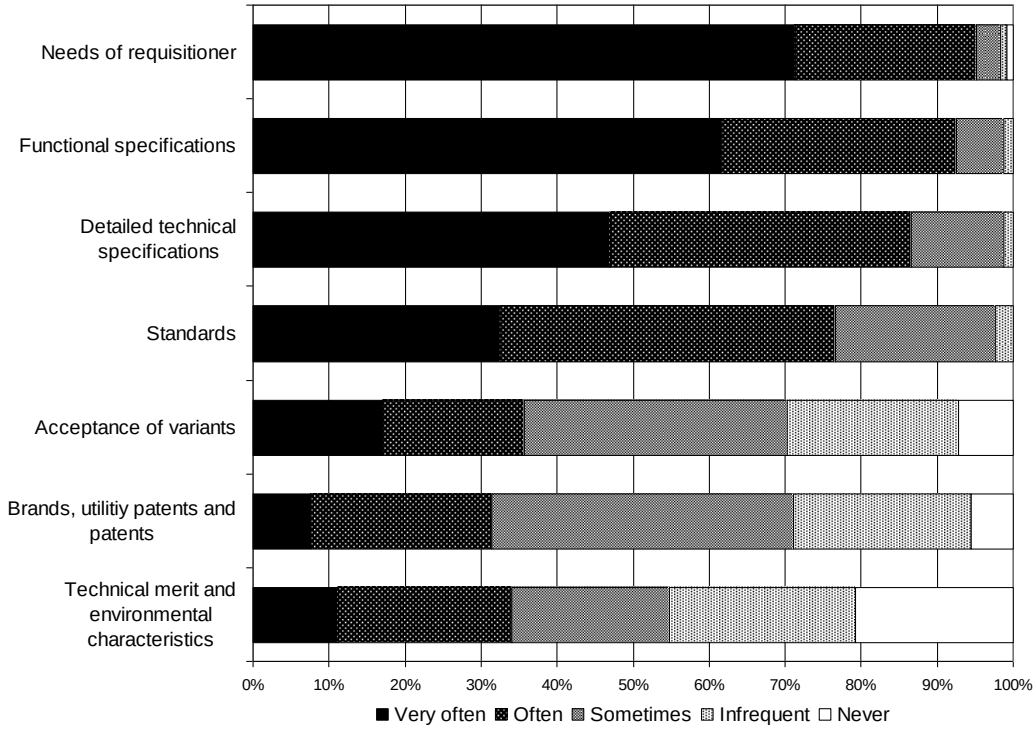
Overall, the empirical studies on the interaction between IPR, especially patents, and standardization underline their ambivalent relationship. However, the limited empirical evidence shows that there is an opportunity to use standardization – often in connection with patent pools – to promote innovation by a more efficient selection, coordination and eventually enforcement of intellectual property rights.

3.5 Standards in public procurement

As already noted by the OECD (2011b) on demand-side policies addressing eco-innovations, the role of public sector's role in contributing to standardization and using standards is not straightforward. Consequently, there is almost no empirical evidence about their impacts available.

Although standards can help to improve public procurement and support the public procurer in the decision processes and risk management, it is interesting to see what is actually happening in practice. A survey among more than 2000 public procurers in Germany, with a response of more than 200, reveals that more than 70% of include standards in the specification of their tenders (Figure 6). An analysis of documents of more than 500 tenders within the European project STEPPIN (www.steppin.eu) funded under the 6th Framework Programmes revealed that 40% indeed reference specific standards, especially the management standards series of ISO 9000 and 14000.

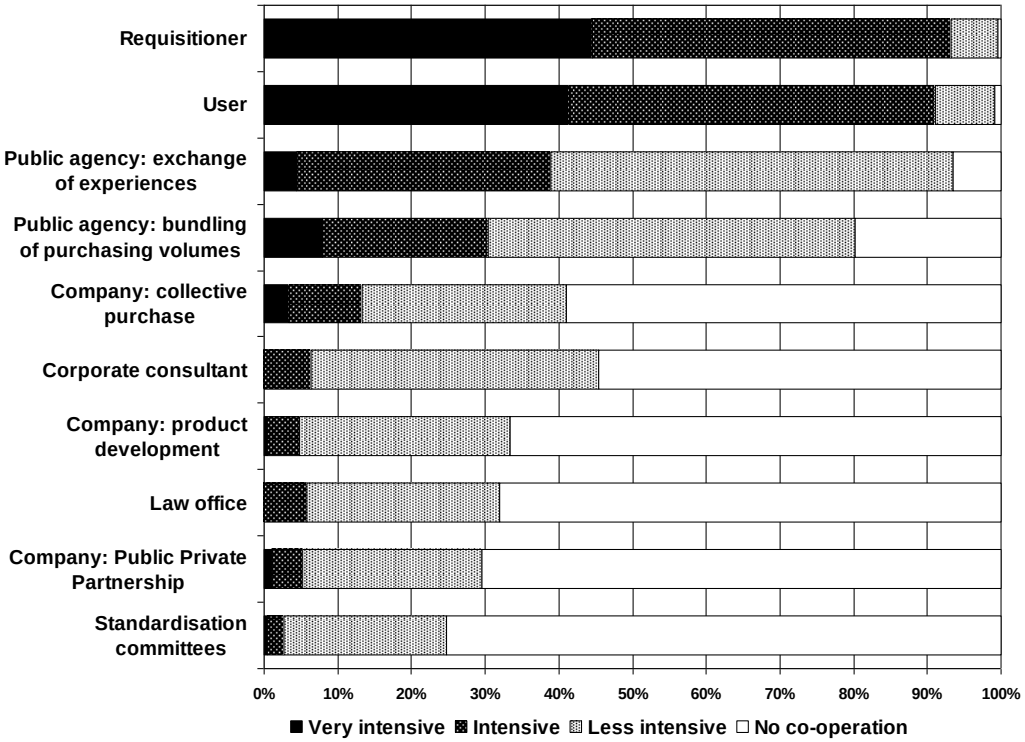
Figure 6: Likelihood of aspects included in the specifications of tenders[16]



The actual practice of public procurers using standards confirms their multidimensional purposes. Both the theoretical considerations and the empirical evidence would suggest that public procurers are not only interested in referencing and using standards in the tendering processes, but also take the opportunity to contribute to the production of standards and to influence the specifications of the standards they are going to use. However, the procurers were also asked about the intensity of their cooperation with stakeholders and institutions. Figure 6 impressively underlines that public procurers do not establish contact with standardization committees during the tendering process. This is a clear indication that they just make use of existing standards, but do not follow or participate in ongoing standardization processes, although they may be influenced by them and even profit from them, e.g. by shaping specifications in the interests of public administrations and eventually the citizens as their customers. The considerable discrepancy between using standards and the lack of contact with standardization committees clearly shows a low awareness among public procurers of the benefits of being involved in standardization processes, although they are convinced about the usefulness of standards for procurement processes and industry, like the European Automobile Manufacturers' Association (2010) endorsed the initiatives of the European Union to support standards setting in the area of Electronic Vehicles to promote their market uptake..

16 Source: Lorenz et al. 2009

Figure 7: Intensity of co-operation with different institutions during the tendering procedure[17]



The actual degree of usage by public procurers indicates that the theoretical considerations about the benefits of standards for the public procurement process have been acknowledged by the majority of public procurers, but interviews have shown that they are not completely aware of the benefits of standards, especially regarding their innovation promoting impacts. In addition, the focus of public procurers on popular management standards shows that they are not fully informed about the whole world of standards. Furthermore, they tend to use very technology specific standards in tenders, which is not very innovation friendly. Finally, public procurers are not involved in standard setting.

4 Summary and Outlook

The review of the existing studies on the impact of standardization and standards on innovation has revealed various major insights, but also shortcomings. In general, there is only very limited empirical evidence of their impact on innovation, whereas a series of studies addressing the macroeconomic impact has been conducted showing indeed a significant positive influence. Regarding innovation, various micro based studies show a positive relationship between companies' involvement in standardization and their spending for research and development on the one hand and their turnover with innovative products. However, the proof of a casual relationship is still missing.

Addressing the specific role of standards for research, researchers confirm the general relevance of standards for all phases of the research and innovation process. The specific

[17] Source: Lorenz et al. 2009

importance of particular types of standards depends crucially on the specific field of science and technology. However, a quantitative assessment of these impacts is missing.

The relationship between IPR and standardization is quite complex and ambivalent. From the theoretical perspective various benefits could be derived, especially if a monopolization of standards by IPR is avoided. In the overview of the very few empirical studies, the ambivalence of the interrelationship and the impacts is confirmed. However, positive examples prove that standardization and standards can be efficiently used to select and coordinate superior IPR, to promote its diffusion and its enforcement.

Finally, the role of standards to promote innovation via public procurement is obvious from a theoretical perspective. However, empirical evidence for this innovation promoting function is not available. On the contrary, the limited available empirical evidence reveals that public procurers do not exploit the innovation promoting impacts of standards for their procurement processes. This is also caused by the missing link between public procurers and standardization bodies and processes.

In summary, the empirical evidence about the various innovation promoting impacts of standardization and standards is both limited and not always supportive. However, the relevance of standardization and standards has been acknowledged in recent, e.g. the German HighTech Strategy and the Lead Market Initiative of the European Commission (Edler et al. 2012), and in forthcoming research and innovation programmes, e.g. Horizon 2020. Consequently, the impacts of standardization and standards will be measured in the following impact assessments after the completion of the various programmes and projects.

Despite the lack of broad empirical evidence, a few general recommendations can be derived how policy makers interested to promote innovation should shape standardization processes and influence the implementation of standards in order to maximize their positive and minimize their negative impacts on innovation. In general, public policy should propose the initiation of standardization processes, especially in those areas of high relevance for society, when industry is reluctant to start because of missing commercial perspectives. Here, standardization foresight exercises (Goluchowicz and Blind 2011) involving all relevant stakeholders might be an exercise initiated by public policy or integrated into more general foresight exercises. Besides the timely initiation of standardization processes, public policy should generate incentives or set rules for standardization bodies to keep the processes open, transparent and consensus-based. This increases the chance to generate solutions, which are balanced between the technology providers, including research organisations, but also between the preferences of the supply and the demand side, including stakeholders representing societal interests of consumers, employees' organisations, like unions, and environmental groups. The specifications of standards should be technology neutral and performance-based – if possible. Regarding the ambivalent relationship between IPR and standards, public policy has to find the balance between offering sufficient incentives for those technology providers owning standards essential IPR and prohibiting anti-competitive behaviour exploiting the combination between network externalities of standards and the temporary monopoly awarded by IPR. Finally, public procurers should make use of the benefits of standards, which can be realised from the very beginning of the whole procurement process not only after its completion. In addition, the public procurer has to be proactively informed about the world of standards, because they can benefit not only from requiring management standards, but also from a large set of technical and even service standards referenced in the technical specifications of tenders. Finally, public

procurers urgently need to be convinced that their input as major actors on the demand side and as possible users of standards is required in standard setting processes

These general recommendations illustrate the multidimensional opportunities for policy makers to make use of standardization processes and standards to promote innovation. However, this numerous options create also a high need for policy coordination (see also Swann 2010), because standardization and standards can be relevant from the very beginning of new technologies, i.e. even in basic research, over a market formation phase until the broad diffusion of innovations via standards. Consequently, various public institutions have to be coordinated along the innovation cycle from research funding organizations, over authorities responsible for IPR, e.g. patent offices, and regulators supervising the market access of new products to public procurers pulling the demand for these product and competition authorities prohibiting the misuse of standard-based market dominating positions.

Table 4: Types of Standards and Role of Public Policy in order to Promote Innovation

	Role of Public Policy to Promote Innovation
Compatibility / Interoperability	• Initiate new standardization processes in case of lock in in old technologies in case of strong network externalities • Ensure compatible and interoperable solutions , e.g. by policy initiatives like the European Interoperability Framework • Promote network externalities by restricting IPR in standards
Minimum Quality/ Safety	• Involve all stakeholders in open, transparent and consensus-based standardization processes • Initiate the development of performance instead of design standards • Reference standards asking for high quality in public procurement
Variety Reduction	• Initiate standardization processes including all relevant stakeholders, incl. public procurers, to develop – if possible technology-neutral – standards in order to promote critical mass in emerging technologies and industries in due time without selecting prematurely specific technologies • Reference standards in public procurement processes to promote the development of critical masses • Ensure that standards including IPR can be implemented by all interested companies in order to avoid market concentration
Information	• Promote the transfer of research results into standardization processes and standards supported by public support programs • Promote the diffusion of the content of standards

References

Aphrodite, K., 2011. Demand-led innovation policies in the United Kingdom – Biometrics standardisation, in (Ed.), Demand-side Innovation Policies, OECD: Paris, pp.169–176.

Arthur, B., 1989. Competing Technologies, Increasing Returns, and Lock-In by Historical Events. The Economic Journal, 99: 116-131.

Baron, J., Blind, K., Pohlmann, T., 2011. Essential Patents and Standard Dynamics. EPIP, Brussels.

Bekkers, R., Iversen, E., Blind, K. , 2012. Emerging ways to address the reemerging conflict between patenting and technological standardization. Industrial and Corporate Change, 21 (4): 901–931.

Berger, F., Blind, K., Thumm, N., 2012. Filing behaviour regarding essential patents in industry standards. Research Policy, 41 (1): 216–225.

Blind, K., 2002. Driving Forces for Standardisation at Standardisation Development Organisations. Applied Economics, 34 (16): 1985-1998.

Blind, K., 2004. The Economics Of Standards: Theory, Evidence, Policy. Edward Elgar: Cheltenham.

Blind, K., 2006a. Explanatory Factors for Participation in Formal Standardisation Processes: Empirical Evidence at Firm Level. Economics of Innovation and New Technology, 15 (2): 157-170.

Blind, K., 2006b. The Influence of Regulations on Innovation: Insights from a European Survey. Wissenschaftsverlag Mainz.

Blind, K., 2008. Driving innovation - standards and public procurement. ISO Focus, Geneva: www.iso.org/iso/livelinkgetfile-isocs?nodeId=15095136.

Blind, K., 2009. Standardisation: a catalyst for innovation. http://www.din.de/sixcms_upload/media/2896/inaugurationsrede_blind_2009.pdf.

Blind, K., Bekkers, R., Dietrich Y., Iversen, E., Köhler, F., Müller, B., Pohlmann, T., Smeets, S., Verweijen, J., 2011. Study on the Interplay between Standards and Intellectual Property Rights (IPRs). European Commission: Luxembourg.

Blind, K., Bierhals, R., Iversen, E., Hossain, K., Rixius, B., Thumm, N., van Reekum, R. , 2002. Study on the Interaction between Standardisation and Intellectual Property Rights. Final Report on Behalf of DG Research of the European Commission: Brussels.

Blind, K., De Vries, H., Wakke, P., 2010a. Driving Factors of Dutch Service Companies to Participate in Formal Standardization: Cross-Sectoral and Sector-Specific Evidence. Proceedings of the 16th EURAS Annual Standardisation Conference , Aachen- pp. 1-16.

Blind, K., Edlera, J., Frietscha, R., Schmocha, U., 2006. Motives to patent: Empirical evidence from Germany. Research Policy, 35 (5): 655–672.

Blind, K., Gauch, S., 2006. Breaking the monolith - differences in ascribed relevance of different standards types in different research contexts. Workshop on Standardisation and Networks, Aachen pp. 119-128.

Blind, K., Gauch, S., 2009. Research and Standardisation in Nanotechnology: Evidence from Germany. Journal of Technology Transfer, 34 (3): 320-342.

Blind, K., Gauch, S., Hawkins, R., 2010b. How stakeholders assess the impacts of ICT standards. Telecommunications Policy, 34 (3): 162–174.

Blind, K., Jungmittag, A., 2008. The Impact of Standards and Patents on Macroeconomic Growth: A Panel Approach Covering Four Countries and Twelve Sectors. Journal of Productivity Analysis, 29: 51-60.

Blind, K., Thumm, N., 2004. Interrelation between patenting and standardisation strategies: empirical evidence and policy implications. Research Policy, 33 (10): 1583-1598.

Blind, K.; Mangelsdorf, A., 2013. Alliance Formation of SMEs: Empirical Evidence from Standardization Committees. IEEE Transactions on Engineering Management, 60 (1): 148-156.

Bozeman, B., 2000. Technology transfer and public policy: a review of research and theory. Research Policy, 29 (4-5): 627-655.

Brunnermeier, S.B., Martin, S. A., 1999. Interoperability Cost Analysis of the U.S. Automotive Supply Chain. National Institute of Standards and Technology: Gaithersburg.

Choi, D. G., Lee, H., Sung, T., 2011. Research profiling for 'standardization and innovation'. Scientometrics, 88 (1): 259-278.

De Vries, H.J., 1997. Standardization –What's in a name? Terminolog, 4 (1): 55-83(29).

Delcamp, H., 2011. Are patent pools a way to help patent owners enforcing their rights?. CERNA, Paris: http://idei.fr/doc/conf/sic/papers_2011/delcampbis.pdf.

DIN, 2000. Economic benefits of standardization. Beuth Verlag: Berlin.

DIN, 2011. The Economic Benefits of Standardization: An update of the study carried out by DIN in 2000. Beuth Verlag: Berlin.

DTI, 2005. The Empirical economics of standards. DTI economic papers: London.

Edler, J., 2013. Review of Policy Measures to Stimulate Private Demand for Innovation. Concepts and Effects.. MIoIR-NESTA: Manchester/London.

Edler, J., Georghiou, L., Blind K., Uyarra, E., 2012. Evaluating the demand side: New challenges for evaluation. Research Evaluation, 21 (1): 33-47.

European Automobile Manufacturers' Association , 2010. Position and Recommendation for Standardization of the Charging of Electrically Chargeable Vehicles. ACEA: Brussels.

Frenz, M., Lambert, R. , 2012. Innovation Dynamics and the Role of the Infrastructure, Report on a research and evidence analysis for the Innovation Infrastructure Project. Report on a research and evidence analysis for the Innovation Infrastructure Project: London.

Gallaher, M. P., O'Connor, A. C., Kropp, B. , 2002. The Economic Impact of Role-Based Access Control. National Institute of Standards and Technology: Gaithersburg.

Ghosh, R. A., 2005. An Economic Basis for Open Standards. European Commission: Maastricht.

Goluchowicz, K., Blind, K., 2011. Identification of future fields of standardisation: An explorative application of the Delphi methodology, in: Technological Forecasting & Social Change. Technological Forecasting and Social Change, 78 (9): 1526–1541.

Guasch, J.L., Racine, J.-L., Sánchez, I., Diop, M., 2007. Quality Systems and Standards for a Competitive Edge. The World Bank: Washington.

Haimowitz, J., Warren, J., 2007. Economic value of standardization. Standards Council of Canada: Ontario.

INTEREST, 2005. Integrating Research and Standardisation: D02. European Commission: Brussels.

ISO, 2011. Economic benefits of standards - International case studies. ISO- Vlume 1 : Geneva.

ISO, 2012. Economic benefits of standards - International case studies. ISO- Vlume 2: Geneva.

ISO/IEC, 2004. Standardization and related activities -- General vocabulary. ISO: Geneva.

Izsak, K., Edler, J. , 2011. Trends and Challenges in Demand- Side Innovation Policies in Europe: Thematic Report 2011 under Specific Contract for the Integration of INNO Policy TrendChart with ERAWATCH (2011- 2012). Technopolis group: Brussels.

Joshi, A. M., Nerkar, A. , 2011. When do strategic alliances inhibit innovation by firms? Evidence from patent pools in the global optical disc industry. Strategic Management Journal, 32 (11): 1139–1160.

Katz, M.L.; Shapiro, C., 1992. Product introduction with network externalities. The Journal of Industrial Economics, 40 (1): 55-83.

King, M. , 2006. Standards and Innovation. Master of Science Dissertation.

Köhler, C., Laredo, P., Rammer, C. , 2012. The Impact and Effectiveness of Fiscal Incentivesfor R&D. NESTA: London.

Konrad, A., Zloczysti, P., 2010. Normung und Innovation sind keine Gegensätze. Wochenbericht des DIW Berlin Nr, 40: 10-14.

Lampe, R. L., Moser, P., 2009. Do Patent Pools Encourage Innovation? Evidence from the 19th-Century Sewing Machine Industry. NBER, : http://www.nber.org/papers/w15061.

Lampe, R. L., Moser, P., 2011. Patent Pools and the Direction of Innovation - Evidence from the 19th-century Sewing Machine Industry. NBER, : http://www.nber.org/papers/w17573.

Lampe, R.L., Moser, P., 2012. Do Patent Pools Encourage Innovation? Evidence from 20 U.S. Industries under the New Deal. NBER, : http://www.nber.org/papers/w18316.

Layne-Farrar, A., Lerner, J. , 2011. To join or not to join: Examining patent pool participation and rent sharing rules. International Journal of Industrial Organization, 29 (2): 294-303.

Leech, D. P., Chinworth, M. W. , 2001. The Economic Impacts of NIST's Data Encryption Standard (DES) Program. National Institute of Standards and Technology: Gaithersburg.

Leech, D.P., 2012a. The Economic Benefits of NIST's Role in the Market Transition to Solid State Lighting Technology. National Institute of Standards and Technology : Gaithersburg.

Leech, D.P., 2012b. The Economic Benefits of NIST's Role in Security Standards Development: X-Ray Standards for Bulk- Explosives Detection. National Institute of Standards and Technology: Gaithersburg.

Leech, D.P., Scott, J.T., 2011. The Economic Impacts of Documentary Standards: A Case Study of the Flat Panel Display Measurement Standard (FPDM). National Institute of Standards and Technology: Gaithersburg.

Lerner, J., Strojwas, M., Tirole, J., 2007. The design of patent pools: the determinants of licensing rules. The RAND Journal of Economics, 38 (3): 610–625.

Lerner, J., Tirole, J., 2004. Efficient Patent Pools. The American Economic Review, 3: 691-711.

Lorenz, O., Lange, M., Rahmann, T., Blind, K., Weber, M., Krohn, W., 2009. "Einkäufer Staat" als Innovationstreiber. Entwicklungspotenziale und Handlungsnotwendigkeiten für eine innovativere Beschaffung im öffentlichen Auftragswesen Deutschlands. Wegweiser: Berlin.

Lundvall, B.-A°., 1988. Innovation as an interactive process: from user–producer interaction to the national system of innovation, in Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Ed.), Technical Change and Economic Theory, Pinter Publishers: London, pp.349–369.

Mangiarotto G., Riillo, C.A.F., 2010. ISO9000 Certification and Innovation: An Empirical Analysis for Luxembourg. 15th EURAS Annual Standardisation Conference "Service Standardization", Lausanne, Switzerland, Jul 1 2010 12:00AM.

Michel, C., 2012. Standardisation of Infrastructure that supports Innovation: The case of the Dutch EV Charging Infrastructure. MSc. thesis.

Miotti, H., 2009. The Impact of Standardization and Standards on Innovation. AFNOR Group: France.

Narayanan, V.K.; Chen, T., 2012. Research on technology standards: Accomplishment and challenges. Research Policy, 41 (8): 1375–1406.

NIST, 2010. Guidelines for Smart Grid Cyber Security: Vol. 1, Smart Grid Cyber Security Strategy, Architecture, and High-Level Requirements. National Institute of Standards and Technology: Gaithersburg.

O'Sullivan, E., Brévignon-Dodin, L., 2012. Role of Standardisation in support of Emerging Technologies: A Study for the Department of Business, Innovation & Skills (BIS) and the British Standards Institution (BSI). Institute for Manufacturing: London.

OECD, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. OECD: Paris.

OECD, 2011b. Driving Eco-Innovation: The Role of Demand-Side Policies. Draft report.

OECD, 2011a. Demand-side Innovation Policies. OECD: Paris.

Rysman, M., Simcoe, T.S., 2008. Patents and the Performance of Voluntary Standard-Setting Organizations. Management Science, 54 (11): 1920-34.

Shapiro, C., 2001. Navigating the Patent Thicket: Cross Licenses, Patents Pools, and Standard Setting, in Jaffe, A., Lerner, J., Stern, S. (Ed.), Innovation Policy and the Economy, Volume 1, MIT Press: Cambridge, pp.119 - 150).

Simcoe, T.S., Graham, S.J.H., Feldman, M. P, 2009. Competing on Standards? Entrepreneurship, Intellectual Property and Platform Technologies, in Entrepreneurship: Strategy and Structure. Journal of Economics & Management Strategy, 18 (3): 775–816.

Standards Australia, 2006. Standards, innovation and the Australian economy. Centre for International Economics : Canberra & Sydney.

Swann G. M. P., Lambert, R., 2010. Why do Standards Enable and Constrain Innovation?. 15th EURAS Annual Standardisation Conference "Service Standardization" , University of Lausanne, Switzerland, Jul 1 2010 12:00AM.

Swann G.M.P. , 2000. The Economics of Standardization: Final Report for Standards and Technical Regulations Directorate Department of Trade and Industry. Manchester Business School: Manchester .

Swann G.M.P., 2010. The Economics of Standardization: An Update. Innovative Economics Limited: Manchester.

Tassey, G., 2000. Standardization of Technology-Based Markets. Research Policy, 29 (4-5): 587–602.