Investigating the Impact of the **Innovation Union**

D4-*1* | Literature Review and Data Collection

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1 Introduction

One aim of the Innovation Union is to create a Single Innovation Market. In order to achieve this goal 5 different commitments have been implemented within the Innovation Union:

- C14: Deliver the EU Patent (including unified system of dispute settlement)
- C15: Screen the regulatory framework in key areas (starting with those linked to eco-innovation and European Innovation Partnerships)
- C16: Speed up and modernise standard-setting
- C17: Set aside dedicated national procurement budgets for innovation. Set up a EU level support mechanism and facilitate joint procurement
- C18: Present an eco-innovation action plan

The following chapters will present for each of these commitments the relevant literature which is the basis for the impact assessment in the next step of this project.

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2 Unitary Patent and the Unified Dispute Settlement System (Commitment 14)

Vanessa Behrens (ZEW)

2.1 Introduction

In the current patent system in Europe, the applicant has the choice of applying at each national patent office (NPO) separately or to file a single application at the European Patent Office (EPO) and subsequently choose in which European countries he wishes to gain protection. The latter choice, the European patent (EP), provides the applicant with a time-saving way of applying for protection. Furthermore, an EP patent is more cost-effective as long as the protection is sought in at least three or four states. However, despite these reductions in costs and administrative work, the current European patent system is still very fragmented, not only in the application process but also in terms of the costs as well as the litigation procedures.

Once the EPO has granted the patent, the applicant is required to select the European states in which it would like to validate the patent. This means that the invention is in fact a second time subject to validation at the national office so that the national office has the ultimate power to grant or unvalidate patents.

In terms of the costs for the applicant, a European patent can quickly become very expensive due to the country designation fees, grant fees, validation fees, national renewal fees and translation costs which accumulate to large sums particularly as the number of designated states increases.[1] Additional external expenses should also not be forgotten. While large firms often have their own intellectual property department, small firms usually have to rely on the services provided by legal advisors and accredited patent attorneys. Helfgott (1993) reported that patent attorney fees in the US averaged around $635 in 1992. Especially compared to other large economies such as the US and Japan, the EP is very expensive. A statistical comparison of the cost is provided by Van Pottelsberghe and François (2009), who show that a European patent that is renewed for 20 years in three (13) EPC Member states costs more than € 43,000 (€ 129,000), against about € 14,500 and € 17,300 for the US patent system and the Japanese patent system, respectively.[2]

In addition to the high costs of an EP, if a patent owner wants to defend his patent in court, he still has to do so in every country in which the patent is valid and the court decisions may differ across

[1] To some extent the London Agreement reduced the burden of translation requirements. See https://www.epo.org/law-practice/legal-texts/london-agreement/key-points.html for more detail.

[2] This calculation is based on the average patent in each patent office and it should be noted that external services expenses are rough estimates and can vary substantially according to the technology and the strategy adopted by the firm.

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countries, even though it is the same patent. Applicants are therefore faced with high uncertainties when several parallel litigation procedures take place and this also has a multiplicative impact on the costs.

In light of these failures of the fragmented European patent system, the forthcoming Unitary Patent (UP) and Unified Patent Court (UPC) provides an opportunity to harmonise and improve the system. With the UP, the application will automatically be valid in 25 EU counties upon grant by the EPO. It will provide uniform protection on a one-stop-shop basis. No validations or translation will be necessary and the patent can be enforced at one single specialised patent jurisdiction – the Unified Patent Court (UPC) – whose decision will be valid across all 25 participating states. This should be a boost for innovation in Europe, especially for SME's (Wolbertus, 2014). The prohibitive cost of patenting, due to the cumulated national renewal fees and the high uncertainties that have resulted from validation and litigation being subject to national patent law are two types of failures that would vanish with the UP (Danguy and van Pottelsberghe de la Potterie, 2009).

Despite its progress, the Unitary Patent is still heavily debated and finding an agreement is a challenging task. Comprising of contributions from an economics, managerial, and legal perspective, this literature review will give an overview of the likely outcomes of the introduction of the UP and UPC by making comparisons to the existing framework. In particular, we will consider the expected impact of the UP on the income of the national patent offices (NPOs) as well as the expected effects on patent demand including substitution effects. This will be followed by literature on the Unified Patent Court.

2.2 Unitary Patent

For the implementation of the UP, two EU regulations have been drafted concerning the geographical protection and the translational arrangements. So far, 25 EU members have agreed to creating UP for their territory. Spain and Croatia however, have chosen not to take part. The UP and Unified Paten Court will come into force when it has been ratified by at least 13 Member States. For any of the (current) 25 Contracting Member States which do not ratify it, the unitary patent will not take effect.

Once the UP has been implemented, the EPO's day-to-day search, examination and granting work will continue as usual, but once the patent has been granted, the applicant will have one month to decide whether to opt for the EP or the new UP. Therefore the EPO expect its' workload to be unaffected by the UP.[3] However, additional tasks of the EPO include the administration of patentees' requests for unitary effect, responsibility for collecting, administering and remitting renewal fees for UPs as well as recording legal-status information such as licenses, transfers, limitations, revocations or lapses.

[3] https://www.epo.org/law-practice/unitary/unitary-patent.html, last visited 20.12.2015.

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With respect to the translation arrangements, no further human translations will be required after the grant of a unitary patent. After a transitional period, the EPO intends to provide high-quality machine translation will be available for the purpose of informing on the content of patents.[4]

The level of UP renewal fees was a heavily debated topic for the UP. In June 2015 an agreement was reached, setting a level roughly equivalent to what patentees currently pay for protection in the four most validated European states.[5] In an earlier study by van Pottelsberghe de la Potterie and van Zeebroeck (2008), they showed that a 15 year old EP patent has protection in about four countries on average. Therefore, summing up renewal fees of the four most designated countries corresponds to what the business sector is currently paying.

A quarter of the EPO's budget is composed of the renewal fees it receives from the NPOs and this highlights the importance of studying the expected effect of the UP in terms of renewal fees. A paper by Danguy and van Pottelberghe de la Potterie (2009) explores the budgetary consequences of the UP by comparing the patent offices' renewal fees income received under the current European patent with the expected income of the forthcoming UP (also known as community patent).

To simulate the expected income of the forthcoming UP, the authors let the income from renewal fees depend on three main factors; the average validation rate of a European patent in a given country, the number of years the patent is renewed – or its maintenance rate – and the level of renewal fees. Since the maintenance rate may depend on many factors (including the renewal fee itself), the authors first try to understand what factors explain the maintenance decisions of granted patents. Results from an econometric model show that five main factors play a significant role. GDP, which reflects the wealth of a country or its' market attractiveness has a positive and highly significant impact on the maintenance rate as well as IPI, which is an indicator of the strength of the national patent system[6]. Countries that have been in the EPC membership for longer (a maximum of 31 years for the founding members) have a higher patent maintenance rate and a patent's maintenance rate decreases with its age. Finally, higher renewal fees reduce the number of years a patent is maintained. The estimated impacts of these five variables allow the authors to derive the maintenance rate of the UP and hence the renewal fees income it would generate for patent offices.

Using the estimated parameters of the maintenance rate in combination with the agreed fee schedule, the authors simulate maintenance rates for the future UP as well as the current EP.[7]

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[4] See https://www.epo.org/law-practice/unitary/unitary-patent.html for more details (last visited 20.12.2015).
[5] https://www.epo.org/news-issues/news/2015/20151118_de.html , last visited 20.12.2015.
[6] Computed by Ginarte and Park (1997) and updated by Park (2008), as seen in Danguy and van Pottelberghe de la Potterie (2009).
[7] Since this paper was written before the agreement on fees was made, the authors actually provide a range of results based on alternative fee levels, which will not be discussed here.

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Under the current EP route, the average cumulative renewal fee income – which depends on the number of validated states and the maintenance rate – is simulated to be around EUR 11,000. This simulated number is close to the truly observed income, providing support of the methodology used by the authors. In comparison, simulation results for the UP suggest that the average patent would generate around €13,600 with the agreed renewal fee schedule.

One critique to the paper is that they look at the complete replacement of the current system with the UP system, bypassing the potential substitution effect that could occur due to the two systems coexisting simultaneously. It was argued that the introduction of the UP would increase revenue because the average revenue from a UP would be larger than the average revenue of a EP, so any substitution would increase revenue. However, if more valuable patens – which are protected in more countries and for a longer duration – are more likely to apply for UP than EP, then it could actually lead to smaller revenue streams. This would mean that the average renewal fee income would be higher for the UP applications compared to the EP application. This substitution effect seems likely, and so it is important to take this into account, since the systems will coexist simultaneously.

Danguy and van Pottelberghe de la Potterie (2014) considered this setting where EP and UP coexist simultaneously, taking substitution effects into account. They simulate the total income that would be generated under a renewal fee scheme very similar to the one that will be implemented and under different substitution levels. They then calculate the average renewal fee income that either the UP or EP would have to generate in order for the patent offices not to be worse off, i.e. to break even. Results show that if 20% of granted patents at the EPO would use the UP-route, then an average UP would generate about €22,000 and an average EP should generate at least €7,525 to ensure the break-even of patent offices.[8] Since the current average revenue generated by an EP is €10,416, patent offices would not be worse off. The greater the share of UP, the faster the system would break even, because in case of a total switch, an average UP generates more revenue than an average EP. Of course break-even would also be reached faster with higher UP fees, which is why national patent offices may have the tendency to implement very high fees. However, the authors stress the importance of finding the right balance between high renewal fees so that patent offices gain more income and low renewal fees to increase the attractiveness of applying the UP-route.

Van Pottelsberghe de la Potterie and François (2009) for example assess to what extent the cost of patenting affects the demand for patents. They construct a measure (which they call the 3C-index) that takes not only the costs into consideration, but rightfully also makes this relative to the number of claims and market size (per capita) of the geographical region in question. They find that the higher the patenting cost per claim per capita, the lower is the demand for a patent. Based

[8] It is assumed that the first patents that will opt for UP will be those that are maintained for longer in the current system.

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on the fee elasticity of a study by de Rassenfosse and van Pottelsberghe de la Potterie, Danguy and van Pottelsberghe (2009) the 45% decrease in relative prices due to the implementation of the UP would induce an 18% increase in the demand for patents at the EPO, all else equal.

On a slightly different note, Harhoff et al. (2009) suggest that increases in fees can be used to reduce the volume of applications, which could facilitate the examination process as well as reduce the time to process applications, given that many marginal patent applications seem to be filed these days. Their paper takes a more international approach and measure the price elasticity of validation and/or renewal fees and translation costs on the geographical scope of protection within the member states of the European patent. The validation (renewal) fee elasticity amounts to -0.1 (-0.3) suggesting that an increase in fees is associated with a decrease in the geographical scope of protection of an EP.

Harhoff et al. (2009) also consider a broader set of strategies related to the geographical scope of protection such as GDP, market size (inhabitants) and the years of EPC membership. Results reveal that a 1% increase in GDP of the applicant (validation) country leads to a 1.7% (0.9%) increase in patent validation flows beyond its national frontiers. A 10% increase in the population size of the applicant (validation) country increases patent validation flows by 8% (3%). Interestingly, this suggests that the wealth (GDP) and market size of the applicant country plays a larger role than the wealth and size of the targeted country. Years of EPC membership of the validation country also have a positive effect on validation flows.

Another important aspect to consider are the translational arrangements. Currently, applications can be filed at the EPO in any language. However, if the application is not filed in English, French or German, a translation has to be submitted. This often requires professional services and one can expect SME to have to rely on external services.[9] Since the costs of translations are not easily observable there are hardly any empirical studies on the expected outcome as a result of the reduced translational requirements of the UP. Harhoff et al. (2009) state that if translation costs were easy to measure, they would assume that they also play an important role in the demand for geographical scope of a EP application. They approximate translation costs and find that an increase in translation costs, reduces the demanded geographical coverage. Hence, one could expect that reductions in translational requirements will increase demand of patents in Europe. Still, the authors stress that one should not put strong emphasis on the findings. The outcome of changes to translational requirements therefore is the hardest to assess. Particularly the overconfidence regarding the ability of machine translations to provide sufficiently reliable translations of the claims is still sceptical.

The choice of how to distribute income across the participating states (the distribution key) also plays an important role for the renewal fee revenue of individual patent offices. Under the current EP-route, the income is distributed depending on the share of total income that each national

[9] https://www.epo.org/applying/basics.html, last visited 21.12.2015.

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patent office generates. This type of distribution key is actually unfair in the sense that it is highly biased in favour of large countries, especially Germany. Danguy and van Pottelsberghe de la Potterie (2009) suggest that GDP or R&D weighting schemes are the fairest and most effective distribution keys. They are easy to compute and actually rewards countries with a high economic performance, which originates from innovative efforts. In November 2015 an agreement was reached which set the distribution key according to allocation formula that regards the gross domestic product and the number of applications filed from each participating Member State. [10]

Given that the UP will reduce costs substantially relative to the geographical coverage, one could expect a general increase in applications. This may reduce the quality if number of examiners don't increase because they will have less time to work on each application. Even without the UP, concerns about low quality patents have been expressed (mainly in US and China), which may increase litigation costs and harm innovation incentives. In 1982, US Congress passed the Paten Law Amendment Act, which resulted in substantially higher patenting costs. De Rassenfosse and Jaffe (2015) explore this quasi-natural experiment to test whether fees are an effective means of weeding out low-quality patents. Some may argue that filing fees would only have a limited effect on patent quality since patent costs are usually modest compared to R&D costs filed early in the life of the innovation and so the ex-ante valuation of the patent may not be the same as the truly observed value ex-post. The contra-argument to the first point is that sunk R&D costs shouldn't be relevant for the application, but rather the expected economic return from a patent and therefore they should have an effect on the potential applications near the margin of economic viability. For the latter argument, the authors refer to an article by Griliches (1990:1699) who explains the two extremes; perfect information vs extremely high uncertainty about the quality of the invention. Under perfect information a rise in the fees would deter the marginal, low-quality inventions from applying whereas too large a degree of uncertainty would make the application decision nearly random and therefore make fees an ineffective screening device. Griliches' opinion is that it is that the truth is somewhere in between. Indeed, Rassenfosse and Jaffe (2015) find that the increase of fees resulted in around 16% of patents from the lowest quality decile to be filtered out[11]. They also find that the fee elasticity of quality decreases with the size of the patent portfolio of applicants suggesting that fees are less effective at weeding out low-quality patents of applicant with a larger patent budget. This further justifies higher absolute renewal fees for the UP as it could be effective at tackling an increase in processing time, as a result of higher demand. However, it is also important to focus on reforms on applicant and examiner incentives rather than simply spending money (Lemley, 2012 and Le Bas and Penin, 2014).

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[10] http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8561&lang=en, last visited 21.12.2015.

[11] The patent quality measure was constructed using indicators such as the number of citations, claims (at grant), the size of the patent family and the number of times the patent was renewed.

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2.3 Unified Dispute Settlement System (UPC)

Patent litigation is of substantial importance in the innovation landscape because it rules on the enforcement of patents, which helps to set their value and significance in the market place. Furthermore, patent enforceability helps to determine incentives to innovate and to commercialize, but at the same time it can determine competitors' incentives to litigate, and even to copy (or not). Providing the right incentives is a difficult act of balancing between the enforceability of patent rights and the costs of litigation. Graham and van Zeebroeck (2014) describe this balancing act as follows:

> *"If courts fail to enforce valid patent rights, or do so too generously in favor of infringers, then infringement will tend to be a dominant strategy. If courts impose complex rules and procedures so that enforcement is made more expensive, then the threat of infringement actions may not be credible, with patent owners enforcing fewer rights at the margin. Similarly, excessively strong IP rights, enforced too severely by courts at a relatively inexpensive price, may produce a greater supply of infringement actions, with possible reduced entry due to excessively high threats of litigation." (page 53)*

With the upcoming introduction of the unitary patent, the European patent litigation system has become an intensively debated topic in recent years. Duplicative litigation, and sometimes even contradictory judgements across European jurisdictions were the major reasons for reforming the current enforcement system. Additionally, forum shopping and high costs are characteristics of the European litigation system that have been recognized for some time. The introduction of the UPC will mean that the UP will be subject to the same legal conditions in all member states. Although the current national European litigation systems will still be upheld in parallel (for non-unitary patent applications), it will be necessary to consolidated these fragmented systems into a single Unified Patent Court (UPC) for a unitary patent to take effect. This will not be an easy task, especially because there are considerable differences between the European courts and institutions and data on court cases has been practically unavailable until very recently and is still limited (in contrast to the Unites States where a stark amount of data exists). This section attempts to provide a thorough review of literature relevant for the Unified Patent Court.

As will become apparent below, there are considerable differences among the jurisdictions of the various legal systems which directly relate to the applicant's costs and incentives of using these courts. These cross-country variations may in turn have important implications for patent enforcement in practice. Graham and van Zeebroeck (2014) provide a nice comparison on the main difference between seven different national European patent litigation systems. The differences existing in the current system, will be discussed below in light of the forthcoming UPC.

The first notable difference is that in contrast to a dual system, some national patent courts have a bifurcated system, where questions on the validity and infringement of a patent are addressed by

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two separate courts, independently. Germany, for example has such a system. Cremers et al. (2014) argue that the bifurcated system in Germany strongly favours the patent holder and the possibility of facing injunction for infringing invalid patents creates substantial legal uncertainty and that firms who have experienced this tend to file more oppositions in a preventative manner in the future. The study also shows that invalidity proceeding take significantly longer than infringement proceedings in first instance. This time lag in decisions is what makes the bifurcated system so problematic. The authors argue that an acceleration of the validity injunctions could address this problem and this should also be kept in mind for the UPC.

Countries also differ in terms of the costs of litigation. The average costs associated with the proceedings, range from a low average of 50,000- 100,000€ for a medium-intensity case in Belgium and Spain, to a high of 150,000-1,500,000€ for a medium-intensity case in the UK (Graham and van Zeebroeck, 2014) with the Netherlands, France and Germany somewhere in between. Patent litigation is expensive and the fragmentation of the system in Europe means that a patentee looking to enforce a bundle of national patents across several European countries is faced with a multiplication of these costs. For these reasons a patentee is unlikely to enforce his patent in each state. This provides an opportunity to freely violate patent rights, especially in the less populous states where it does not pay off for the patent holder to litigate from a financial perspective (Swanson, 2013). In light of the UPC is it therefore interesting to quantify the cost of duplication that arises from such parallel litigation. Harhoff (2009) does precisely this. His study groups cost and benefit effects into the following categories: (i) effects from avoiding duplication of litigation; (ii) effects from changes in the demand for litigation, induced by changes in the cost structure; (iii) effects from changed incentives for patenting. Harhoff strongly recommends to proceed with the efforts to establish a unified and integrated patent litigation system for European patents and the future UP. His conservative estimates of the relevant parameters, the economic benefits from such a system are likely to exceed the costs of the establishment and operation of the new court by a large multiple of between 5.4 and 10.5.

Cremers et. al (2013) also compared patent litigation cases under the current EP system across four European jurisdictions; Germany, France, the Netherlands and the UK. The authors provide summary statistics on the case characteristics such as the outcomes, process times and duplication of cases. Their discussion on the main country differences highlights the fragmentation between the enforcement systems. The authors argue that there is scope for parallel litigation under the current system since most of their sample of EP patents is validated in all four jurisdictions. Using a unique dataset on litigation cases, their sample reveals that the share of duplicated cases (i.e. same patent and litigation parties in multiple jurisdictions) is low in Germany (2%) and France (6%), but rather high in the UK (16%) and the Netherlands (26%). Overall the vast majority of patents are only litigated once. Other differences highlighted in the study are the share of settlements. More than 60% of cases in Germany end with a settlement, whereas this is true for only around 40% of cases in the UK. The time it takes to obtain a judgment in the first instance for infringements is less than one year in Germany, the Netherlands, and the UK. Infringement cases take almost one year longer in France to reach a decision. Claims for invalidity are decided fastest in the UK (within less than a

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year), but take considerably longer in Germany (on average 18 months). Cremers et al. (2013) also find that courts appear to specialize in types of industries. Courts in the UK show a concentration on companies in pharmaceuticals/chemistry and in electronic products whereas litigating companies in Germany are concentrated mostly in the areas of machinery and engines. A great advantage that is expected from the UPC is the ability to tailor towards industry specific matters. Since the UPC would hear the majority of cases, it allows for customization of paten law for each industry. In contrast to the US, the UPC would also employ technically qualified judges in validity proceedings, which is where these expertise are most needed (in comparison to infringement cases).

The outcome of cases also appears to differ according to the country. Revocation is the most likely outcome in UK courts, regardless of whether the initial claim is for infringement or revocation. In contrast, infringement is the most likely outcome in German and Dutch courts. Notable in France is the large share of patents that is held not to be infringed (but valid).

These cross-country differences underline the potential for forum shopping. Additionally though, the lack of UPC has meant that patent law has continuously been interpreted differently by the patent courts across Europe in an attempt to expand competence of cross-border adjudication. Swanson (2013) discusses how the ECJ has persistently ruled against these interpretations made by the courts with specific cases. Dutch courts for example, understood that Article 5(3) gave them the right to order cross-border injunctions.[12] This led them to exercise jurisdiction over foreign patents and give injunctive remedies against infringement in other countries. Originally this was used to protect Dutch patentees, but by 1994 they had interpreted patent law to give them competence over infringement of foreign patents, as long as the defendant was domiciled in Netherlands. In the case of *Shevill and others versus Press Alliance* the ECJ held that Article 5(3) gives courts competence only with respect to damages that occurred in the state where the court sits. Graham and van Zeebroeck (2014) argue though that Dutch courts continue to receive a large number of cases in a sort of forum-shopping manner as a consequence of this concept that infringement can be held at the international level combined with the *KortGeding* procedure present in Dutch courts (enabling preliminary injunctions). Before the ECJ made a decision on the case of *Roche Bederland BV versus Primus*, patent holders interpreted Article 6(1) to allow them to sue all infringers of a European patent at the same time in one court, so long as one of the infringers was domiciled in the court's state.[13] The court would then reason its ability to adjudicate infringement for foreign patents because it would apply foreign law to foreign patents. The ECJ rejected this line of reasoning. For the case of *Gesellschaft für Antriebstechnik mbH & Co. KG versus Lamellen und*

[12] Aricle 5(3) provides that „[a] person domiciled in a Member State may, in another Member State, be sued: … in matters relating to tort, delict or quasi-delict, in the courts for the place where the harmful event occured or may occur", as seen in Swanson (2013) page 174.

[13] Articel 6(1) states that „[a] person domiciled in a Member State may also be sued where he is one of a number of defendants, in the courts for the place where any one of them is domiciled, provided the claims are so closely connected that it is expedient to hear and determine them together to avoid the risk of irreconcilable judgements resulting from separate proceedings", as seen in Swanson (2013) page 175.

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Kupplungsbau Beteiligungs KG, Swanson states that the ECJ clearly gave courts the competence to decide on questions on infringement of foreign claims (following the *lis pendens* rule and Article 2) but that adjudication on validity is exclusively reserved to the courts where the patent is registered (Article 22(4)).

Hence, infringement has a more international reach whereas validity is strictly decided upon at national level. This allows defendants to respond to infringement claims in a strategic manner, such as the 'Italian Torpedo' strategy. Since the court first seized always takes precedence over the courts seized after, an infringer can strategically choose the first forum in which he files a claim on invalidity to be particularly slow, like the Italian court. This defers injunctions and damage awards that the infringer has to pay the patentee and drawn-out actions often lead to settlements benefiting the defendant (Swanson, 2013).

For UPC it is actually intended that actions for revocation will generally be brought before the central division, and actions for infringement will be brought before a local/regional division in a member state in which the infringement has occurred, or where the defendant is domiciled. This means that one considerable aspect of the reform is that the system allows for a choice between bifurcation and an integrated process for hearing infringement and invalidity cases. In order to avoid Italian Torpedos in the UPC, Swanson (2013) suggests that all non-infringement declaratory judgements should be brought before the central division (UPC) and that actions for non-infringement must be stayed once the patent holder brings an infringement suit.

2.4 Summary

Overall, the literature has positive expectations of the UP and UPC. The UP with a unified jurisdiction would reduce both the costs and uncertainty currently associated with the fragmented European patent system. At the same time quality in the examination process is expected remain stable as a result of higher absolute renewal fees. The cost savings, lower complexity and wider geographical coverage would make the patent system more accessible for SMEs. It also makes the European market much more attractive for both domestic and foreign applicants. Forum shopping should be reduced because of having technically qualified judges on most panels, so that litigants cannot exploit the disparities between divisions in technical familiarity. This is further strengthened by the fact that the Court of First Instance judges will be assigned from a central pool of judges, so litigant won't be guaranteed that certain judges will take part in their case. Given the large geographical expansion of coverage, an increase in renewal fees is justified and patent offices of smaller countries would actually largely benefit from the UP, because they have a relatively low revenue with the current European patent, due to the very low validation rate.

2.5 Data Collection

In order to assess the impact of the Unitary Patent, we would like to use patent data to compare

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the composition of the applicants for the different filing routes availible. How many applicants choose the UP-route and do applicants that have a status of being an SME account for a disproportionately larger share of UP-applications compared to EP-applications? However, it is not yet possible for inventors to apply for patents with unitary effect. Therefore this data is not yet availible. Since litigation procedures tend to happen several years after application, any kind of data collection with regards to the Unified Patent Court seem to be unachievable for the purpose of this report.

2.6 References

Cremer, K., M. Ernicke, F. Gaessler, D. Harhoff, C. Helmers, L. McDonagh, P. Schliessler and N. van Zeebroeck. (2013). "Patent Litigation in Europe". ZEW Discussion Paper No. 13-072.

Cremers, K., F. Gaessler, D. Harhoff, C. Helmers. (2014). "Invalid but Infringed?An Analysis of Germany's Bifurcated Patent Litigation System". ZEW Discussion Paper.

Danguy, J. and B. van Pottelberghe de la Potterie. (2009). "Cost-Benefit Analysis of the Community Patent". Bruegel Working Paper.

Danguy, J. and B. van Pottelberghe de la Potterie. (2014). "The Policy Dilemma of the Unitary Patent". Bruegel Working Paper.

De Rassenfosse, G. and A. B. Jaffe. (2015). "Are Patent Fees Effective at Weeding out Low-quality Patents?" Motu Economic and Public Policy Research.

Graham, S. J. H. and van N. van Zeebroeck. (2014). "Comparing Patent Litigation Across Europe: A First Look". Stanford Technology Law Review, Vol. 17(655).

Helfgott, S. (1993). "Patent filing costs around the world". Journal of the Patent and Trademark Office Society, Vol.75(7), p.567-580.

Harhoff, D. (2009). "Economic Cost-Benefit Analysis of a Unified and Integrated European Patent Litigation System". Report for the Institute for Innovation Research,Technology Management and Entrepreneurship, Tender No. MARKT/2008/06/D.

Harhoff D., K. Hoisl, B. Reichl and B. van Pottelsberghe de la Potterie, (2009), Patent Validation at the Country Level – the Role of Fees and Translation Costs, Research Policy, 38(9), pp. 1423-1437.

Le Bas, C. and J. Penin. (2014). "Patents and innovation : Are the brakes broken, or how to restore patents' dynamic efficiency?"

Lemley, M. A. (2012). "Fixing the Patent Office". SIEPR Discussion Paper No. 11-014

Swanson, R. D. (2013). "Implementing the E.U. Unified Patent Court: Lessons from the Federal Circuit". Brigham Young University International Law and Management Review, Vol. 9(4).

Van Pottelsberghe, B. and D. François. (2009). "The Cost Factor in Patent Systems". Ind Compet Trade 9:329–355.

Van Pottelsberghe de la Potterie, B. and van N. van Zeebroeck (2008). "A Brief History of Space and Time: the Scope- Year Index as a Patent Value Indicator Based on Families and Renewals".

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CEPR Discussion Paper No. 6321.

Wolbertus, R. (2014). "The effects of the Unitary Patent on innovative Small and Medium Enterprises in the Netherlands". Technische Universiteit Eindhoven, Master Thesis Identity number 0639486.

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3 Regulatory Framework (Commitment 15)

Sandra Leitner (wiiw)

3.1 Introduction

It is a widely accepted notion that in addition to internal technological, organizational and managerial capabilities, innovative activities of firms are also strongly affected and shaped by the particular regulatory environment they operate in. In general, policy-makers can avail of two different types of instruments to encourage and foster the development and diffusion of innovation and technology, namely (i) market-based instruments like taxes, subsidies or fees or (ii) command-and-control-type of instruments like (design or performance) standards or bans. Regulations are found to matter at every single stage of the complex innovation process *(Pelkmans and Renda, 2014)* and depending on how they are designed and implemented, regulations can be either conducive or obstructive to innovation. Hence, given the generally observable productivity, growth and employment-enhancing effects of innovation, a well-designed, efficient, goal-oriented and effective regulatory framework is essential to induce entrepreneurs to engage in innovative activities in the first place and eventually bring about the socially desirable effects.

From a theoretical point of view, the existence of so-called *'market failures'* which lead to socially sub-optimal outcomes and result in decreases in economic welfare, is the key prerequisite in economics for regulations. However, in addition to market failures, regulatory interventions also become necessary in situations of *'regulatory failures'*, when existing rules and regulations produce sub-optimal outcomes. For instance, *Pelkmans and Renda (2014*) stress that outdated or inflexible regulations or regulations that cause substantial administrative burdens or compliance costs may lead to socially sub-optimal results and hinder further innovation. Similarly, the *EC (2014*) emphasizes that inconsistent rules and practices in the EU hamper the development of high-growth innovative firms, which often consider it too difficult or risky to operate in other European markets. And *NRTEE (2009)* highlight that inefficient regulations may impede technical progress. Regulatory interventions are also inevitable if particular *long-term policy goals* need to be achieved like stronger innovative efforts in desired fields like eco-innovation or faster transition to newer technologies without unnecessary adaptation lock-ins, to name but a few.

Hence, in view of the importance of regulations for innovation in general and the detrimental effects regulatory failures have on innovative activities in particular, rules and regulations need to be reviewed regularly for inconsistencies, regulatory rules need to be constantly screened and carefully adapted and new ones need to be implemented to set the right incentives for present and future innovators. This is also highlighted in Commitment-15 of the Innovation Union, which states that: '*Starting in 2011: EU and Member States should undertake a screening of the regulatory framework in key areas, starting with those linked to eco-innovation and to the European Innovation*

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Partnerships. This will identify the rules that need to be improved or updated and/or new rules that need to be implemented in order to provide sufficient and continuous incentives to drive innovation. The Commission will provide guidance on how best to organize this screening exercise.'

In this context, the role of the regulatory framework for eco-innovation, on the one hand, and the European Innovation Partnerships (EIPs), on the other, will be discussed in sections 2 and 3, respectively, and some empirical evidence will be provided to establish the strong regulation-innovation nexus. Section 4 briefly discusses the 6-step approach that was developed on behalf of the EC to screen the regulatory framework and presents the main findings of two screening exercises that have so far been performed of (i) the EIP-Water and (ii) the EIP-Raw Materials. Finally, section 5 summarizes and concludes.

3.2 Eco-innovation and the regulatory framework

Recently, in the EU, eco-innovation[14] has received a fair amount of attention from economists and policy-makers alike for its potential to address two of the EU's current key problems: first, climate change and second, sluggish growth and persistently high unemployment, legacies of the global financial crisis of 2008.

Generally, from a theoretical point of view, two reasons are highlighted which necessitate environmental regulations to help stimulate eco-innovation. First, following the so-called Porter-hypothesis (Porter and van der Linde, 1995), well-designed environmental regulations are needed to induce entrepreneurs to invest in R&D and eco-innovate, which not only increases their 'private' productivity, competitiveness and profitability, but also benefits the society as a whole. This is a classical win-win situation. Second, eco-innovation is characterized by a so-called 'double-externality problem' due to two positive externalities: knowledge externalities, on the one hand, and externalities due to the positive impact on the environment, on the other. This gives rise to a double market failure, which calls for regulations to avoid underinvestment in R&D and to realize the socially desirable level of investment in eco-innovation.

Empirical evidence strongly supports the notion that regulations are of key importance for and help stimulate eco-innovation. In line with and support of the Porter-hypothesis entrepreneurs are found to be more eco-innovative in the face of more stringent regulations (*Doran and Ryan, 2012*; *Horbach, 2008*; *Horbach et al., 2012*; *Horbach et al., 2013*; *Kammerer, 2007*). However, more importantly, the effect of regulations tends to differ by type of environmental impact and innovation, highlighting that regulations are not able to stimulate all different types of eco-

[14] According to the European Commission (2011) '*Eco-Innovation is any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources*'.

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innovation. In this respect, *Horbach et al. (2012)* use the German Community Innovation Survey conducted in 2009 and show that current and expected government regulations induced German entrepreneurs to reduce air emissions (i.e. CO_2 and other air emissions) as well as water or noise emissions, avoid hazardous substances and increase the recyclability of material, waste and water. On the contrary, no (statistically significant) effect of either present or future regulations was found for German entrepreneurs' decisions to reduce material use or energy use. In a similar vein, firm-size also seems to matter for the effectiveness of regulations in stimulation eco-innovation. *Tiguero et al. (2013)* use the EU-wide Flash Eurobarometer #315 that was conducted in 2011 among around 5,000 managers of SMEs in 27 EU Member States in some selected sectors to study the drivers of eco-innovation among European SMEs. They demonstrate that while existing regulations trigger both product and organizational eco-innovation, they, however, fail to stimulate process eco-innovation among SMEs. On the contrary, future regulations did not play any statistically significant role for any type of eco-innovation.

However, regulations not only induce entrepreneurs to invest in eco-R&D and develop and introduce eco-innovation, but also to invest more in eco-R&D, rendering regulations also an important determinant of the resources spent on eco-innovative activities. *Kesidou and Demirel (2012*) study a set of UK manufacturing firms and show that the stringency of environmental regulations strongly matters for the amount of resources allocated to eco-innovative activities, inducing entrepreneurs to spend more on environmental innovations.

3.3 European Innovation Partnerships (EIPs) and the regulatory framework

The EC defines European Innovation Partnerships (EIPs)[15] as a new, challenge-driven approach to EU research and innovation, focusing on societal benefits and a rapid modernization of the associated sectors and markets. Accordingly, "*EIPs should act across the whole research and innovation chain, bringing together all relevant actors at EU, national and regional levels in order to: (i) step up research and development efforts; (ii) coordinate investments in demonstration and pilots; (iii) anticipate and fast-track any necessary regulation and standards; and (iv) mobilize 'demand', in particular through better coordinated public procurement to ensure that any breakthroughs are quickly brought to market.*"[16]

Regulation in general is understood as a public sector intervention intended to affect the behavior of economic agents towards a desired direction. In the context of regulatory policy intervention into the working of partnerships as collective ventures, the rationale for such interventions should draw on the fact that the state has a number of specific abilities and capacities which are superior

[15] As of 2015, the EU has launched five EIPs: EIP on Active & Healthy Ageing; EIP Water; Agricultural Productivity & Sustainability EIP; EIP on Raw Materials; EIP on Smart Cities and Communities.
[16] http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=eip

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to those of private agents/stakeholders. Such regulatory interventions should therefore be focused on the exploitation of these abilities both in the process of policy design and in policy implementation *(Dobrinsky, 2009)*.

The state has – due to its power to enforce – a greater ability than the market to deal with externalities, especially when it comes to complex, systemic ones. It is thus conjectured that the state has a superior ability and capacity to address "systemic" failures, involving a large number of agents/stakeholders and complex links and interactions among them. *Arnold and Thuriaux (2003)* point out several such failures:

- Failures in social institutions (such as universities and research institutes, public regulatory and policy implementation offices, etc.) amounting to their inability to perform efficiently their functions, with negative consequences to agents/stakeholders that rely on these functions.
- Network failures, which have to do with problems in the interaction among different agents/stakeholders (e.g. due to poor interlinkages among them, low degree of trust, high perceived transaction costs, unsupportive market structure, etc.).
- Capability failures in firms and other stakeholders, which come to their inability to act in their own best interests (e.g. due to poor managerial or technological skills, deficits of or inability to absorb externally generated technologies).
- Framework failures, related to difficulties in the broad framework conditions (such as unsupportive regulations, dysfunctional regulatory bodies, poor business environment, mismatches in social and cultural values, etc.), with negative implications for innovation activity.

EIPs, being such complex and large ventures, are undoubtedly prone to be affected by systemic failures of this sort. Therefore, the EIP regulatory framework would also need to be screened from this perspective.

At the micro-level, the rationale for policy intervention is often formulated in terms of assistance to market agents and other stakeholders to jointly achieve mutually agreed goals. A common refrain in the policy rationale and objectives is that of targeting better connectivity among stakeholders *(Boschma and Lambooy, 1999*; *Lambooy and Boschma, 2001*). As stakeholders only possess incomplete information, policy has a role in facilitating the flow of relevant information or knowledge to those involved in a project. Such functional roles for the public sector (such as aligning the incentives of different stakeholders; establishing mechanisms of sharing the risks in multi-stakeholder ventures; facilitating the process of match-making between potential partners; promoting information- and knowledge-sharing in multi-stakeholder ventures, etc.) are consistent with the promotion of "economies of scope" (in contrast with the traditional rationale of promoting economies of scale).

The role of EU regulations in facilitating connectivity and collaboration among EIPs stakeholders to achieve mutually agreed goals could form a third perspective of screening the EIP regulatory framework.

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An important rationale for policy intervention in the knowledge economy is to address specific information and knowledge externalities, by stimulating a process of "discovery" that would help filling knowledge gaps that restrain entrepreneurship *(Hausmann and Rodrik, 2003*; *Rodrik, 2004*). Typical examples of such externalities are those related to the underlying cost structure of the economy that entrepreneurs face when introducing a new product: in this situation entrepreneurs discover what it actually costs to produce the product when producing it. This is an entrepreneurial problem faced by all investors in innovation and its implications are equivalent to a knowledge-related market failure.

Undoubtedly, entrepreneurial discovery plays a leading role in the innovation process especially as regards the ambition "to achieve innovative breakthroughs" as one of the EIPs' objectives is formulated. Thus the role of existing regulation in incentivizing entrepreneurial discovery within the EIPs could be another perspective of screening the EIP regulatory framework.

Finally, within the regulatory monitoring one could seek to analyze and identify incidences of "regulatory framework failures" per se, i.e. possible cases (if such exist) when the existing regulation may not facilitate but de factor hamper the effective and efficient functioning of EIPs.

3.4 Screening of the regulatory framework

As outlined above, as part of Commitment 15, the EC is responsible to provide guidance on how to best organize regulatory screening exercises. In this respect, commissioned by the EC, *Peter et al. (2014)* identified and specified the following six-step methodology to shed light on the complex regulation-innovation interplay, which allows policy makers to perform a gradual, systematic evaluation of the effects of regulation on innovation and to formulate concrete policy recommendations:

Step 1: Determination of the area for assessment
In most cases, the impulse to select a particular area comes from an internal review or external feedback from stakeholders. Identifying the relevant regulations and framework conditions requires interaction between policy makers and other stakeholders in the field. Policy makers inevitably need to agree on a point of departure for their screening, such as specific sectors, types of regulation or particular regulatory agents and levels. Choosing a broad focus tends to complicate the identification of relevant drivers for innovation, whereas a strong emphasis bears the risk that important factors remain unconsidered.

Step 2: Scoping the area in focus
After having agreed on an area, more needs to be learned about the area's actors, innovation needs and importance for society as a whole. The particular focus has important repercussions for the level of detailed information that has to be gathered at this stage of the screening process.

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Statistical data should be used to gain insights into the relevance and structure of the area, complemented by qualitative feedback from various stakeholders.

Step 3: Identifying drivers of and barriers for innovation
With the information acquired, analysts will then be able to classify specific innovation effects of regulation. While direct effects can be easily detected, unraveling the numerous indirect or unintended effects can pose a real challenge. As policy makers will most probably be interested in improving regulations, identifying drivers and barriers in various areas can give a comprehensive understanding of what needs to be done.

Step 4 – Screening of regulatory landscape relevant for the area in focus
Analogous to step 3, the relevant regulation is identified and classified by type and objective. The classification of *Blind (2012)*, which categorizes regulation broadly in economic, social and institutional objectives, constitutes a useful standing point for this undertaking. In most cases, it will not be easy or even possible to narrow down single pieces of regulation as it is the interplay of various laws and provisions that is decisive for the final innovation effects.

Step 5 - Analyzing the links of regulation and innovation
Policy makers can then use the collected information to shed light on the possible links between regulation and innovation. For that purpose, they can make use of two methodologies that were developed from practical experience: the framework of *Stewart (2010)*, which evaluates regulations by their flexibility, promotion of complete information in the market and stringency, or of *BERR (2008)*, which adds a perspective on the importance on timing and differentiated compliance costs. As costs and benefits of new regulations will likely be distributed unequally among different stakeholders, the involvement of a wide range of different groups can help to keep track of potential winners and losers to allow for a balanced reform proposal.

Step 6 – Formulating recommendations
Finally, the complex analysis performed in the previous five steps needs to be narrowed down to concrete policy recommendations. The knowledge gained about direct and indirect effects of regulation on innovation for different stakeholders should enable an informed and well-conceived choice of policy.

3.4.1 Impact of regulation on innovation in the field of water: EIP-Water

A screening of the regulatory framework in the European Innovation Partnership on Water (EIP-Water) following the six-step approach outlined above indicates that lack of funding, high costs and lack of demand are considered to be the major barriers to innovation, whereas both existing and expected future regulations rank high among the drivers of eco-innovation in this area. From these existing regulations, the *Water Framework Directive (WFD, 2000)* is the most relevant

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regulation, directly and indirectly driving innovation. By signaling a growing demand to European companies in the water sector, it contributes to the diffusion of new water technology. Generally, existing EU legislation is seen as an important driver of innovation. By imposing stricter standards, room for innovation is provided as compliance with new rules requires investment in new technologies. On closer consideration, environmental regulations are found to be the most influential in promoting technological innovation in the water sector whereas economic regulations predominantly act as barriers. The authors recommend further development of regulations to address the big imminent challenges in this field, but caution that inconsistent policies can hamper innovation.

3.4.2 Impact of regulation on innovation in the field of raw materials: EIP-Raw Materials

Similarly, the regulatory framework in the European Innovation Partnership on Raw Materials (EIP-Raw Materials) was screened. The scoping process of waste management and recycling identified a few multinational enterprises together with many small municipal providers as major actors. Unfortunately, innovation in the area remains relatively low in the EU, with all Member States ranking behind the US and Japan. In an attempt to divert waste from landfills, many countries invested heavily in relatively low-cost incineration technologies, which is considered one of the major barriers for the development of innovative recycling programs, as they are currently not able to compete with incineration commercially. More potent regulations in addition to fiscal measures might be necessary to promote cleaner and more resource-efficient technologies. In the field of mining, regulation focuses on environmental issues as most sites are located outside of Europe. These regulations were often identified as a barrier to the construction of new exploitation sites as they require time-consuming planning procedures, also due to non-concerted permitting processes within national and regional authorities. Innovation itself does not seem to be particularly important for the big multinational firms dominating the sector as it would entail longer-term investment that is not economically viable due to short concession periods.

3.5 Summary

Regulation - as state intervention – which is intended to affect the behavior of economic agents towards a desired direction and to achieve socially desirable outcomes in situations of (market, regulatory or systemic) failures or to accomplish longer-term policy goals, is considered key to innovation. Hence, to remove barriers and foster innovation, rules and regulations need to be reviewed regularly for inconsistencies, regulatory rules need to be constantly screened and carefully adapted and new ones need to be implemented to set the right incentives for present and future innovators. This regulatory screening exercise is of particular importance in key areas where regulation is found to play a central role like (i) eco-innovation, which addresses some of the EU's current key problems namely climate change, sluggish growth and persistently high

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unemployment, and (ii) the European Innovation Partnerships (EIPs), which represent a new, challenge-driven approach to EU research and innovation.

To allow policy-makers to systematically evaluate the effects of regulation on innovation and screen the prevailing regulatory framework in particular areas, a six-step approach was developed by *Peter et al. (2014*). Its first application in the areas of water and raw materials (i.e. EIP Water and EIP Raw Materials) shows that, with respect to water, environmental regulations are the most influential in promoting technological innovation in the water sector, that the *Water Framework Directive (WFD, 2000)* is the most relevant regulation, directly and indirectly driving innovation but that further regulation needs to be developed to address the challenges in this area. With respect to raw materials, the screening exercise stresses that current regulation is more of a barrier to innovation in the area of recycling and to the use of secondary raw materials and that more potent regulation is necessary to promote cleaner and more resource-efficient technologies.

3.6 References

Arnold, E. and B. Thuriaux, 2003, Introduction, in: European Commission, Future directions of innovation policy in Europe, Innovation Papers, 31, 1-9.

BERR, 2008, Regulation and Innovation: Evidence and policy implications.

Blind, K., 2012, The impact of regulation on innovation, Manchester Institute of Innovation Research.

Boschma, R. and J. Lambooy, 1999, Evolutionary economics and economic geography, Journal of Evolutionary Economics, 9(4), 411-429.

Dobrinsky, R., 2009, The Paradigm of Knowledge-Oriented Industrial Policy, Journal of Industry, Competition and Trade, 9(4), 273-305.

Doran, J. and G. Ryan, 2012, Regulation and Firm Perception, Eco-Innovation and Firm Performance, MPRA Paper No. 44578.

EC, 2014, State of the Innovation Union, Taking Stock 2010-2014, Commission Staff Working Document, Brussels.

EC, 2011, Innovation for a sustainable Future - The Eco-innovation Action Plan (Eco-AP), Brussels.

Hausmann, R. and D. Rodrik, 2003, Economic development as self-discovery, Journal of Development Economics, 72(2), 603-633.

Horbach, J., 2008, Determinants of environmental innovation – New evidence from German panel data sources, Research Policy, 37, 163-173.

Horbach, J., V. Oltra and J. Belin, 2013, Determinants and Specificities of Eco-Innovations Compared to Other Innovations – An Econometric Analysis for the French and German Industry Based on the Community Innovation Survey, Industry and Innovation, 20(6), 523-543.

Horbach, J., Ch. Rammer and K. Rennings, 2012, Determinants of eco-innovations by type of environmental impact – The role of regulatory push/pull, technology push and market pull,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

Ecological Economics, 78, 112-122.

Kammerer, D., 2009, The effects of customer benefit and regulation on environmental product innovation. Empirical evidence from appliance manufacturers in Germany, Ecological Economics, 68, 2285-2295.

Kesidou, E. and P. Demirel, 2012, On the drivers of eco-innovations: Empirical evidence from the UK, Research Policy, 41, 862-870.

Lambooy, J. and R. Boschma, 2001, Evolutionary economics and regional policy, Annals of Regional Science, 35(1), 113-131.

NRTEE, 2009, Achieving 2050: A Carbon Pricing Policy for Canada, Technical Report.

Pelkmans, J. and A. Renda, 2014, Does EU regulation hinder or stimulate innovation?, CEPS Special Report No. 96, November 2014.

Peter, V., G. van der Veen, A. Doranova and M. Miedzinski, 2014, Screening of regulatory framework, Technopolis Group.

Porter, M.E. and C. van der Linde, 1995, Toward a new conception of the environment-competitiveness relationship, Journal of Economic Perspectives, 9(4), 97-118.

Rodrik, D., 2004, Industrial policy for the twenty-first century, CEPR Discussion Papers No. 4767, Centre for Economic Policy Research: London.

Stewart, L., 2010, The Impact of Regulation on Innovation in the United States: A Cross-Industry Literature Review, (June), 1–29.

Triguero, A., L. Moreno-Mondéjar and M.A. Davia, 2013, Drivers of different types of eco-innovation in European SMEs, Ecological Economics, 92, 25-33.

WFD, 2000, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

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4 Standardisation (Commitment 16)

Bettina Peters (ZEW)

4.1 Introduction

Standards are rules, guidelines or characteristics that products, processes or services have to meet, e.g. with respect to dimension, quality, performance, or safety. For a long time, standards and innovation have been viewed as contradicting each other (Blind 2013) because innovation is the realization of something new while standards are meant to hold things the same (Mangiarotti and Rillo 2014). As a result of this conviction, innovation policy has mainly focused on the regime of Intellectual Property Rights (IPRs) and R&D subsidies or tax credits as policy tools in order to stimulate innovation. Standards, however, did not belong to the innovation policy toolkit. They have largely been neglected as policy instrument to stimulate innovation (Blind 2013).

In recent years, however, it has increasingly been emphasized that standardization and standards can also be seen as an important mechanism for knowledge transfer. In the course of the standardization process the parties involved often exchange tacit knowledge about research results, technical specifications and technical solutions. And standards – as outcome of the standardization process – themselves may include relevant technical information on the preferred technology or technical specification which is publicly available for free.[17] Therefore, they can also be seen as a mean to disseminate research results and outcomes of innovation activities. As such they can play an important role in stimulating follow-up innovation activities (Blind 2013). But standards may also change the ex-ante incentives to invest in innovation in the first place (Aoki and Schiff 2014).

The observation that standards are increasingly seen as an important tool for knowledge transfer and valuable input into innovation processes, also relates to the fact that standardization has become more common in the last two decades. Figure 1 shows the development of annual standards production at the International Organization for Standardization (ISO) over the period 1996-2014. The number of new and revised standards published has increased by about 80% from 817 in 1996 to 1468 in 2014. In terms of the number of published pages the production has even more than doubled in this period.[18] Of course, during this period some standards have also be withdrawn or superseded by new ones. Taking this into account and looking at the development of the stock of standards, we observe a similar growth. The stock of ISO standards has grown by 91% over the period 1996-2014, from 10745 in 1996 to 20493 in 2014. ISO standards cover a broad range of fields, covering almost every industry, from technology, to food safety, to agriculture and

[17] Implementation is in general free of charge. Some standards are associated with compensating payments (royalties) to owners of related IPR, mainly patents (Blind et al. 2011).

[18] From 33199 published pages in 1996 to 68497 pages in 2014.

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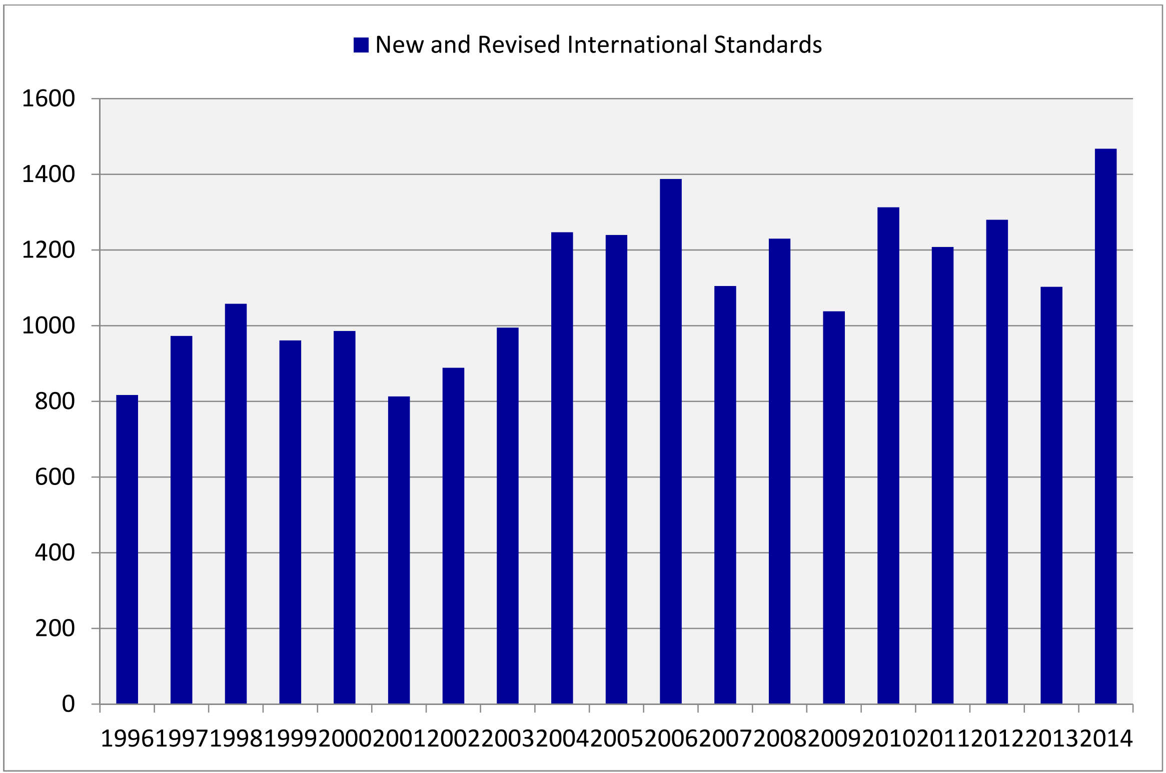
healthcare. The distribution of ISO standards across sectors is given in Figure 2. More than 37% of standards produced in 2014 were related to engineering technologies, followed by material technologies (18%) and electronics and ICT (16%).

Figure 1 Annual Standards Production at ISO, 1996-2014



Source: ISO annual reports of different years, own calculation.

One reason that might explain this development is a greater pressure on industry to rationalize so that industry has become more interested in the role of standardization and in assessing its economic efficiency. But predominantly, the surge in standardization is driven by the fact that many products and services are nowadays based on interoperable yet independently supplied component technologies. As a result, some form of coordination is important in order to ensure compatibility and interoperability of technologies or technical systems and network reliability (David and Greenstein 1990, Rysman and Simcoe 2008). This form of coordination ultimately aims at enabling firms to create more valuable products and services for consumers.

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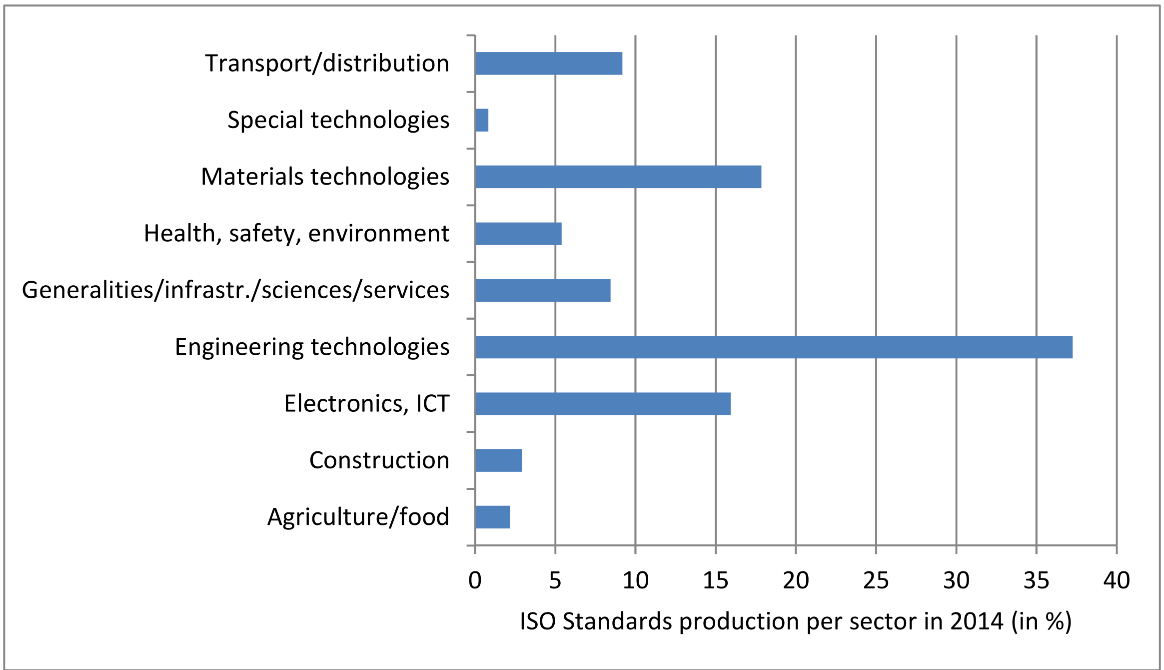
Figure 2 Annual Standards Production at ISO by Sector, 2014



Source: ISO figures 2014.

Technical standards that target compatibility and interoperability are traditionally most prevalent in the field of information and communication technologies (ICT) and consumer electronics (ITU 2014). Hence, it is not surprising that the tremendous rise in standards is even more pronounced for standards related to ICT. ICT standards deal with telecommunications, broadcasting and other electronic communications networks and services and they include fixed, mobile, radio, converged, broadcast and Internet technologies. ICT standards can be handled and published by various Standard-Setting Organizations (SSOs) but the two most important organizations are the International Telecommunication Union (ITU) for worldwide ICT standards and its European counterpart, the European Telecommunications Standards Institute (ETSI) for European ICT standards.[19] Figure 3 impressively shows the surge in ICT standards produced by ETSI over the period 1991 to 2014. In has increased from 49 standards in 1991 to about 2500 to 3000 standards per year in the last five years. The total stock of standards produced by ETSI amounted to 36932 at the end of 2014. In addition to its pure increase, Simcoe (2007) also pointed out that the type of ICT standards have evolved over time from the definition of simple specifications to the joint development of large technology platforms, including many patented components.

But technical standards targeting compatibility and interoperability are increasingly important and

[19] ETSI was founded in 1988. Although ETSI was originally established to produce ICT standards for Europe, ETSI increasingly collaborate with partners worldwide in order to produce standards for global use, e.g. within the Third Generation Partnership Project (3GPP) or the development of the Machine-to-Machine communications systems oneM2M.

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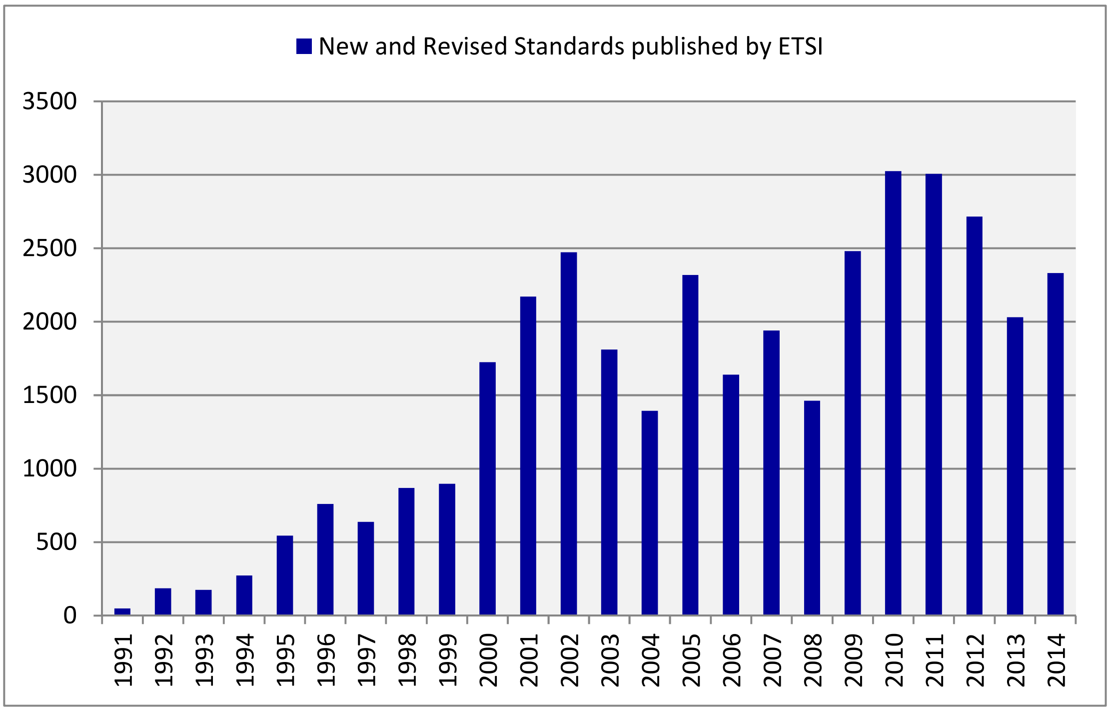
demanded by other industries as well. Due to the fact that ICT is a general purpose technology used in all industries, the latter demand ICT standards that are either purpose-built or adapted to the requirements of markets not traditionally involved in the ICT standardization process (ITU 2014). Examples include ICT-enabled services such as e-health, intelligent transport systems, mobile money, smart grid or smart metering technologies for water, gas and electricity which all heavily rely on compatibility standards (ITU 2014).

By facilitating compatibility and interoperability and thus also reducing uncertainty, technical standards may also encourage companies to innovate in order to differentiate their products, offer complementary products or to rationalize production methods.

Figure 3 Annual Standards Production by ETSI, 1991-2014



Source: ETSI (2015), Connected World – Annual Report 2015.

Acknowledging the positive role standardization (as process) and standards may play for technology transfer and stimulating innovation, the EU has placed a much stronger emphasis on standardization as policy tool to stimulate innovation within the *Innovation Union* flagship initiative. Commitment 16 is dedicated to increase the awareness of the European Standardization Systems and to speed up and modernize the standard-setting process in order to enable interoperability and foster innovation in fast-moving global markets. Technical standards are also a key pillar of the *Digital Agenda for Europe*, another flagship initiative within Europe 2020. A similar shift in the evaluation of standards for innovation policy as in Europe can be observed in other countries like the US (implemented in the *Strategy for American Innovation: Securing Our Economic Growth and Prosperity*) and China (Breznitz and Murphree 2011).

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This chapter investigates the relationship between standards and innovation. The following three sections provide more detailed information about standards and the standard-setting procedures in Europe. It starts by defining standards and relevant concepts as well describing the main aims and functions of standards in section 4.2. Section **Fehler! Verweisquelle konnte nicht gefunden werden.** gives a brief overview of commitment 16, i.e. standard-related aims and activities within the Innovation Union. Section **Fehler! Verweisquelle konnte nicht gefunden werden.** describes the current standard-setting process at European SSO. Intellectual Property Rights (IPRs) are often an important issue with standard-setting processes and the role of standard essential patents and patent pools are explained in section **Fehler! Verweisquelle konnte nicht gefunden werden.**. Section 4.5 provides theoretical predictions and empirical findings on the relationship between standards and innovation while the effect of standards on economic growth is summarized in section 4.6. Section 4.7 describes the data collection and section 4.8 concludes.

4.2 Definition of Standards and Standardization

This section first provides a general definition of standards and starndarization. Basically, we can distinguish two types of standards, so called ***de facto*** and ***de jure standards***.
De facto standards can be created in a variety of ways. De facto standards may emerge in situations when different firms offer competing incompatible technologies or solutions and an overwhelming majority of consumers adopt a particular technical solution which then becomes the de facto (industry-wide) standard. Well-known examples are the operating system of Microsoft or the network technology Ethernet promoted by Intel, Xerox and DEC (which later became a de jure standard). These proprietary standards can be closed which means that they canonly be used by the firm and its customers and partners whereas competitors are banned from implementing products that use closed proprietary standards. On the contrary open proprietary standards are also owned by a single firm, yet anyone is allowed to use them. In order to establish a de facto standard, a firm has different strategic options, including licensing, entering into strategic alliances or diversifying into offering complementary products (Hill 1997). De facto standards are often the result of standards wars (Chiesa and Toletti 2003). But it might also be that a group of companies (*consortium*) informally negotiates about technical specifications of components or systems (Delcamp and Leiponen 2012). These informal agreements about common specifications can also become an industrial standard which again can either be protected, e.g. by one or more patents, or it can be used for free by everybody (Blind 2002).
In contrast, de jure standards emerge as voluntary standards through standard-setting organizations (SSOs) organized by private parties (Chiao et al 2007). In the following, we (mainly) focus on the role of de jure standards.

The ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission of Standardization) set the specialized system for worldwide standardization.

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Currently, general terms and definitions concerning standards, standardization and related activities are laid down in the ISO/IEC Guide 2:2004 (8th edition).

According to ISO and IEC (2004) a de jure ***standard*** is a published *normative document* that is approved by a recognized body and 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. Standards should reflect state-of-the-art knowledge which means that they are based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits.

Standardization is the processes of formulating, issuing and implementing standards. The standardization process in all standard-setting organizations follows certain core principles. Most importantly, standardization is a ***voluntary*** process and standards are established by ***consensus*** (ISO and IEC 2004). How consensus is actually defined depends on the specific rules of the standard setting organizations. Typically, it requires more than a simple majority but it doesn't necessarily imply unanimity among the participating parties but rather the absence of sustained opposition to substantive issues (Rysman and Simcoe 2008, ITU 2014). It is an ***open process*** that aims at involving different kinds of stakeholders in order to achieve its commitment to transparency, openness, effectiveness, relevance and coherence. Again, depending on the standard setting organization and the type of standard considered different actors can be actually involved in the process. These are industry in the first place, but also consumers, workers, academia, interest groups like environmental stakeholders and public authorities can be part of the standardization process (Blind 2013).[20] ***Transparency*** of the process is another important characteristic. That is, the public must be informed about the beginning of the preparation of a standard, about the body preparing it, about the document serving as the basis for its preparation and about the preparation stages (public enquiry, issue of the standard). Finally, standardization should avoid conflicting standards. The ***coherence*** of standards collection implies that an old standard is withdrawn when a new standard on a subject is adopted.

The subjects of standardization are ***products, processes and services*** in a broad sense. This equally covers, for example, any material, component, equipment, system, interface, protocol, procedure, function, method or activity (ISO and IEC 2004). Characteristics to be standardized are e.g. related to interoperability, dimensions, quality, performance or safety.

As already explained, a standard is a normative document. Other related normative documents include technical specifications, codes of practice and technical regulations (ISO and IEC 2004).

- A ***technical specification*** is a document that contains a prescription of the *technical requirements* that have to be fulfilled by a product, process or service. A technical specification should indicate, whenever appropriate, the procedure(s) by means of which it

[20] For more details on the standard-setting process in European SSO see section **Fehler! Verweisquelle konnte nicht gefunden werden.**.

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may be determined whether the requirements given are fulfilled. Importantly, a technical specification may be a standard, a part of a standard or independent of a standard.

- In contrast to technical requirements, recommendations on *practices or procedures for the design, manufacture, installation, maintenance or utilization of equipment, structures or products* are summarized in a document called ***code of practice.*** Codes of practices are also called *service standards*. Examples include storage of liquids, laying floor coverings, laundry practice for white and colored washing, and information security. Like for technical specifications, a code of practice may be a standard, a part of a standard or independent of a standard.
- In contrast to standards which are the outcome of voluntary agreements, a ***technical regulation*** is a document that provides binding legislative rules adopted by a legal authority. It prescribes *mandatory technical requirements* such as product certification requirements, performance mandates, testing procedures, conformity assessments and labeling standards, either directly or by referring to or incorporating the content of a standard, technical specification or code of practice. A technical regulation can be supplemented by technical guidance that outlines by which means the requirements of the regulation can be fulfilled (deemed-to-satisfy provision). Though standards describe voluntary technical requirements they may cover mandatory technical requirements as well.

4.3 Direct Aims and Types of Standards

This section briefly summarizes the main direct aims of standards and different types of standards that can be deducted from these aims.

It is important to note that standards (and technical regulations) exist for very different reasons. According to ISO and IEC (2004), overall standards are aimed at

(i) improving the suitability of products, processes and services for their intended purposes;

(ii) preventing barriers to trade and

(iii) facilitating technological cooperation.

The ***main direct purposes*** that are pursued with implementing standards range from ensuring or improving fitness for purpose, compatibility, interoperability, interchangeability and variety control to health, safety, protection of the environment, and product protection (cf. ISO and IEC 2004).

- ***Fitness for purpose*** generally means that a product, process or service is able to serve a defined purpose under specific conditions.
- ***Compatibility and interoperability*** means that products, processes or services are suitable for joint use under specific conditions without causing unacceptable interactions. Compatibility and interoperability is particularly important in the ICT and consumer

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electronics sector (David and Greenstein, 1990). However due to the general purpose technology character of ICT, it has increasingly become an objective of standardization in other industries as well.

- ***Interchangeability*** denotes the ability that one product, process or service can be replaced by another in order to fulfil the same requirements.
- ***Variety control*** implies the selection of the optimum number of sizes or types of products, processes or services to meet prevailing needs.
- ***Safety*** of products, processes and services means the freedom from unacceptable risk of harm. Defining safety, often involves finding an optimal balance of a number of factors, including non-technical factors such as human behavior that will eliminate avoidable risks of harm to persons and goods to an acceptable degree.
- ***Protection of the environment*** means the preservation of the environment from unacceptable damage from the effects and operations of products, processes and services.
- ***Product protection*** is the environmental protection (deprecated) or the protection of a product against climatic or other adverse conditions during its use, transport or storage.

These purposes are not exclusive and they can also overlap for a given standard. Given the fact that standards are established to serve a wide range of purposes, different ***types of standards*** can be distinguished:

- A ***semantic*** **or** ***terminology standard*** covers definitions of terms which may be accompanied
  by explanatory notes, illustrations, examples, etc. They are particularly important in health and pharmaceuticals in order to prevent misunderstandings, e.g. to select single worldwide acceptable names for each active substance (ITU 2014). Defining terms is also particularly important for emerging technologies.
- A ***measurement standard*** contains definitions of measures. This includes e.g. standards on the measurement of mass as kilogram, length as meter or electric current as ampere.
- A ***testing standard*** provides test methods which may be supplemented with other provisions related to testing such as sampling, use of analytical and statistical methods or sequence of tests.
- A ***product standard*** specifies requirements for a material or product to be fulfilled to achieve its fitness for purpose. This may include requirements for dimensions, performance, packaging, labelling, methods of sampling and test methods. Thus, it provides guidelines for producing, processing, selling, purchasing and using the product. Note that a product standard can specify requirements on all these issues or only on parts, e.g. only on material. Product standards are the most prevalent type of standards. *Process standards* and *service standards* are defined analogously.
- A ***technical standard*** provides requirements for technical systems, specifying standards engineering criteria, methodologies or processes. Compatibility and interoperability are the

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most important criteria for the functioning of technical systems, e.g. to ensure that a mobile phone and a mobile network successfully interact with each other. Hence, they are also called *compatibility standards, interoperability standards* or *interface standards*.

- ***Safety standards*** are designed to ensure the safety of products, processes or services.
- ***Management standards*** describe management rules and guidelines, e.g. related to quality management systems, environmental management systems, banking transaction documentation, production management, logistics or inventory management.

Based on this list of different types of standards we can conclude that there is a large heterogeneity in standards. As a result different standards fulfill different function(s) and might be associated with different indirect benefits which will be explored in more detail in the next section.

4.4 Indirect Benefits and Costs of Standards and Standardization

In addition to generating direct benefits - fitness for purpose, compatibility, interoperability, interchangeability, variety control, health, safety, protection of the environment, and product protection – standards might be associated with several **indirect benefits** which are closely related to their functions (see Blind and Gauch 2009).

- ***Reduction of transaction costs:*** As already mentioned one important function of standards is to ensure compatibility and interoperability between components. By increasing compatibility of products and components standards reduce transaction costs, e.g. adaption costs (David and Greenstein 1990, Blind and Gauch 2009).
- ***Technical coordination***: The interoperability function of standards also facilitates technical coordination and cooperation among independent producers (Rysman and Simcoe 2008). It may also lead to a bandwagon process among adopters and mitigate hold-up problems by promoting open technology (Besen and Farrell 1991, Farrell and Saloner 1988). Standards can also facilitate future networking with other researchers, industries and stakeholder.
- ***Generating network externalities***: Compatibility between products might furthermore generate positive network externalities among users (Blind and Gauch 2009). For example, many machines and objects are nowadays embedded with sensors that can communicate over the internet (called Internet of Things). The communication, however, is impeded by the fact that individual devices that make up these Internet of Things have disparate platforms, proprietary software, protocols and network options. The OneM2M standard setting process initiated at ETSI will provide a standardized interface so that different devices can be connected irrespective of the underlying network (ETSI 2015).

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- ***Provision of complementary goods:*** Coordination through standardization improves furthermore the incentives and abilities to develop, produce and sell complementary goods (Chiao et al. 2007).

- ***Dissemination of knowledge:*** Standards and standardization exert an information function as they can be seen as a mean to disseminate research results and more broadly speaking knowledge. Standards are thus seen as a catalyst of technical knowledge diffusion (Gamber et al. 2008). On the one hand, the parties involved in the standardization process often exchange *tacit* knowledge about research results, technical specifications and technical solutions during the process. On the other hand, standards – as outcome of the standardization process – embed relevant technical information on the preferred technology or technical specification. They usually represent the state of the art in science, technology, tools and techniques. Given the fact that this relevant knowledge is not only codified but also publicly available for free or for a mostly cost covering fee, it can be more easily diffused than for example knowledge codified in patents (Blind and Jungmittag, 2008, Blind et al. 2011). By exchanging knowledge and appropriating external knowledge, firms' R&D activities should become more efficient. Hence, standards can play an important role in stimulating follow-up innovation activities (Blind 2013).

- ***Reduction of information costs***: Standards may have an additional information function. They can increase the flow of information between producers and consumers regarding the inherent characteristics (like compatibility and interoperability) and quality of products. That is, efficient and non-discriminatory standards allow consumer to compare products on a common basis in terms of regulatory characteristics. Hence, uncertainty about product quality is reduced (Jones and Hudson 1996). This increased transparency of product information may enhance competition (David and Greenstein 1990) and may encourage firms to improve the quality and reliability of their products.

- ***Achieving economies of scales***: Standardization lowers the number of different types of one product so that producers whose goods are subject to standards could achieve economies of scale and reduce overall production costs and therefore prices (Blind 2002, Chiao et al. 2007).

- ***Reduction of maintenance and repair cost:*** Maintenance and repair is less difficult with standardized products and technologies (Blind 2002).

- ***Overcoming market failure***: Environmental or safety standards may be an important instrument for solving or mitigating market failure (Stephenson 1997). Food safety standards, e.g., ensure that consumers are protected from health risks and deceptive practices. Information about these risks is generally not made public by producers to consumers. Environmental standards like emission standards on the other hand are designed to get firms to keep an acceptably low degree of environmental damage (Maskus et al. 2005).

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- ***Facilitating trade***: Standards can also foster trade via different channels. In this context, it is especially important to distinguish purely national and international standards and their role on trade flows. Purely national standards are not consistent with relevant international standards. Both types of standards can reduce information asymmetries and thus uncertainty between domestic sellers and foreign customers or vice versa and as a result stimulate trade (Leland, 1979). In particular, complying with international standards increase export opportunities due to the larger size of the market on which firms can offer their products and services. Larger markets might additionally lead to the exploitation of greater economies of scale (Chiao et al. 2007).

These indirect benefits can be mainly seen as static benefits. But some of them are directly or indirectly related to innovation activities and might thus also lead to dynamic benefits in terms of stimulating innovation. We will discuss the interplay between standards and innovation in more detail in the following section 4.5. Before looking at this relationship in more detail, we will briefly discuss potential **indirect costs** associated with the use of standards.

- ***Costs of disclosure and lost of control***: From a firm's point of view there exists a trade-off between making its technology publicly available in the course of a standard setting process and benefiting from a larger market and potentially also from licensing revenues on the one hand and remaining closed to reduce competition and maintain control of their knowledge assets on the other hand (e.g. Shapiro and Varian 1998, Gawer and Henderson 2007). In particular firm with higher sensitivity upon appropriation may be reluctant to contribute to standardization. In contrast to patents which make codified knowledge publicly available, standardization processes often additionally involve the risk of leakage of tacit knowledge as well (Blind 2006). Chiao et al. (2007) stressed the importance of disclosure costs even for already-issued patents. Due to the number and complexity of patent portfolios, rivals frequently cannot determine which patents are relevant to a given standardization effort. By highlighting the essential patents or patent applications, firms may disclose to competitors valuable information about the applicability of their patent portfolio and their future technological strategies in general. Such an early disclosure of plans may invalidate the ability to get future awards.

- ***Opportunity costs of participating in standardization:*** Participation in standardization is associated with opportunity costs. Firms which participate in these processes have less time for other research, for writing papers and it also means to be restricted in the commercialization of the research results (Blind 2013). These opportunity costs hence reduce the incentives to join standardization processes.

- ***Limiting competition:*** Standard setting can also be misused by forcing firms to exit the market or by limiting market access from new firms. Standards might feed this antitrust concern if they are associated with significant increases in production costs. Some standards that e.g. involve high performance, compatibility or safety requirements may significantly raise set setup and production costs (Maskus et al. 2005). Higher production

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costs might force some firms to exit the market and they might prevent new firms from entering the market. As a result standards may impede competition (Fischer and Serra 2000). When they put foreign producers at a disadvantage, they may constitute a non-tariff barrier to trade.[21] This is probably more likely to happen in standard setting processes in which not all relevant parties are involved like consortia.

- ***Delays due to standardization:*** Standardization processes take time which may create some delays in the knowledge transfer process (Blind 2013). It may also lead to a delay in the marketing of a new product which firms want to include in a standard (Blind 2002).

- ***Raising conflicts***: Standards might also create conflicts between the actors involved (Blind 2013).

4.5 Standards and Innovation

This section describes in more detail the interrelationship between standards and innovation. A recent literature survey based on bibliometric methods has shown that this research field has significantly grown importance over the last two decades. Choi et al. (2011) found that number of publications has increased from roughly 13 articles in 1995 to about 68 in 2009. We structure our literature survey on standards and innovation around five major themes. First, we deal with the question to what extent innovation acts as a driver for firms to participate in standard setting processes Second, we investigate the question how given standards affect the incentive to invest in innovation. Third, we focus on whether SSO and their rules affect innovation. Fourth, we specifically investigate the relationship between standards and Intellectual Property Rights. And finally, we address the issue of patent pools and their relationship to innovation.

4.5.1 Innovation as Driver for Participating in Standardization

Firms have to decide whether to actively participate in standardization processes or not. The underlying motives of this decision might be manifold. Blind and Gauch (2009) studied the motives to join standard setting organizations for German firms in nanotechnology which is an emerging and dynamically growing science field. Based on expert interviews they report that among those researchers that are actively involved in standardization, the most important motives for participation are shaping specifications of standards and addressing specific technical problems. In addition, for companies it is an important motive to prevent the market dominance of proprietary standards and to prevent certain specifications to be integrated into standards. But almost equally important is it to facilitate jointly agreed rules leading to interoperability, compatibility and common terminology, to increase own technical know-how and time-lead advantage over non-participating competitors as well as to foster the commercialization of own research results.

[21] Data on non-tariff barriers to trade can be gathered from the Worldbank's WITS Databank.

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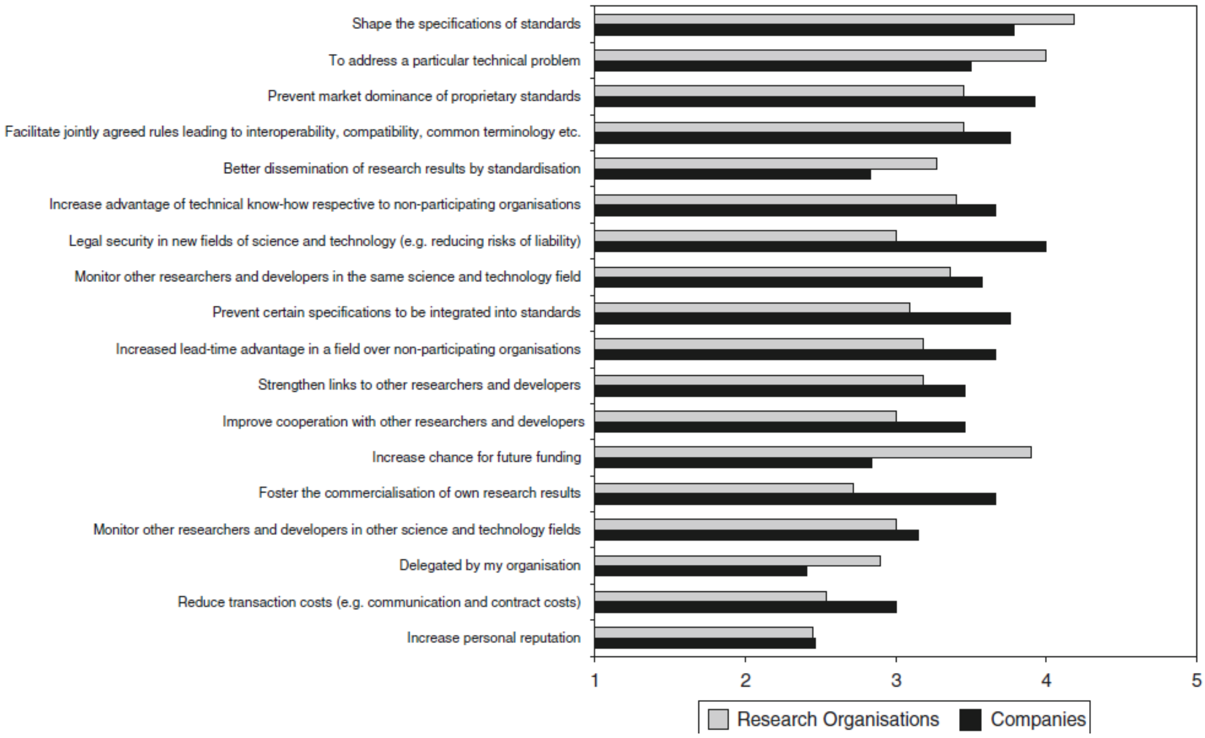
Figure 4 Motives for participating in standardization by type of organization



Note: Likert scale: 1: very irrelevant, 5: very relevant
Source: Blind and Gauch (2009).

In particular the latter finding suggests that firm's own research and innovation activities act as a driver for participating in standardization. In theory, opposing effects are expected. On the one hand, the standardization process can be seen as a continuation of the product development phase of internal R&D (Blind 2002). Having invested in own research activities and successfully developed new technologies that may be relevant for inclusion in standards, firms' willingness to participate in standardization processes may increase. Firms potentially gain from being included in the standard due to a larger diffusion of the technology and as a result of the expected larger market and demand. Therefore R&D-performing firms are more likely to standardize (Farrell and Saloner 1985). But on the other hand, they must bear the costs of standardization which includes the actual financial costs of a standardization process but also the indirect costs, in particular the costs of disclosure, delay and opportunity costs (see also section 4.4). Therefore, R&D-intensive firms might be more reluctant to participate in standardization processes. Finally, it is argued that less R&D-intensive firms might be more likely to participate in standardization in order to benefit from rivals' R&D activities via knowledge transfer (Love and Roper 1999, Blind 2006). However, Cohen and Levinthal (1990) stressed that firms need absorptive capacities – generally built up through own R&D activities – in order to absorb external knowledge and integrate it into own innovation processes.

Only a few empirical studies have investigated the role of innovation for participating in

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standardization activities. Blind (2002) studied the *effect of innovation on standardization at the sector level*. Using data for 19 industrial sectors in Germany and the period 1991-1995, the paper estimates the effect of sectoral R&D expenditure (as innovation input indicator) and patent applications (as indicator for innovation output) on the average publication of standardization documents of sector i. Standardization documents are taken from the German National Standardization Institute (DIN) as well as from around 150 other German standardization institutes and it also includes European and international standards adopted in Germany. They find that R&D-intensive sectors produce significantly lower number of standards when the patent protection intensity is low. Under these circumstances firms are not willing to make internally generated knowledge publicly available within the standardization process. If, however, the industry is better able to protect their knowledge via patent applications, the willingness to contribute to standardization increases. That is, industries with a high number of patent applications produce significantly more standards. This finding confirms that IPRs play an important role for standardization. Furthermore, there is an inverse U-shaped relationship between concentration and standardization. Standardization increases with the concentration of the firms up to a certain threshold, where standardization activities decline again. Furthermore, they find evidence that export-intensive sectors standardize significantly more frequently than non-export-intensive sectors. These findings were confirmed for 20 sectors and 7 countries (Germany, Spain, France, UK, Netherlands, Japan and the US).

Instead of investigating sector-specific driving forces for standardization, Blind and Thum (2004), Blind (2006), Blind and Mangelsdorf (2013) and Blind et al (2011) studied the *effect of innovation on standardization at the firm level*. Using a small sample of 149 European firms mostly large and from research intensive industries, Blind and Thum (2004) investigated the role of R&D intensity and patent intensity on the likelihood of joining a standardization process. That is, in contrast to Blind (2002), the dependent variable doesn't measure the standardization output but is a binary variable indicating whether the firm has participated in formal international standard setting organization (SSO) activities. Their regression results show no significant correlation between the R&D intensity and participation while there is a significant negative correlation between the patent intensity and the likelihood of joining SSO activities. One reason for the weak results might be potential non-linearities in the effect of innovation on joining SSO activities. Blind (2006) empirically investigates the participation of German firms in formal standardization processes at national, European or international level. Not surprisingly they find that larger firms are more likely to participate in standardization. More importantly, they find that the likelihood to join formal standardization processes increase with R&D intensity up to a certain threshold above which the likelihood decreases again. This inverse U relationship implies that participating in SSO activities requires a certain absorptive capacity, but firms with a high R&D-intensity are reluctant to join standardization processes as they expect more disadvantages, like unintended knowledge spillovers. They also find an inverse U relationship for exporting firms. That is export activities increase the likelihood to join formal standardization processes up to a certain level, but firms with very high export shares are less likely to participate. One explanation could be that high export shares indicate that firms are able to adapt its product portfolio successfully to specifications and

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preferences of various domestic markets, so that international standards threaten or devalue this competitive advantage. Blind and Mangelsdorf (2013) specifically focus on *small- and medium-sized enterprises* (SMEs) and their decision to participate in standardization activities. Using data of German firms in the electrical engineering and machinery industry, they find similar driving forces for SMEs as Blind (2006). In particular, they confirm the inverse U relationship between R&D intensity and SSO activities. Initially, an increasing R&D intensity increases the likelihood of SMEs to join SSO activities in order to access the knowledge of (larger) firms. But above a certain threshold R&D activity they become more reluctant to participate in standardization because they expect their knowledge to be too essential to disclose to competitors. The importance to access external knowledge via SSO activities is underlined by a positive correlation with the relevance of incoming knowledge spillovers and a negative correlation with the relative size of firms' patent portfolios. Blind et al. (2011) studied the effect of innovation on standards at firm level for *service firms*. They matched Dutch Community Innovation Survey data with a list of firms that are active in the Dutch standardization institute NEN. In contrast to Blind (2006) and Blind and Mangelsdorf (2013), they find a linear positive relationship between R&D intensity and SSO activities. However, using an innovation output indicator (share of sales with market novelties) they again confirm an inverse U-shaped relationship.

To sum up, all empirical studies detect a significant relationship between innovation activities and the engagement in formal SSO activities. Most of the empirical evidence is in favor of an inverse U-shaped relationship. However, one should keep in mind that this does not necessarily imply a causal relationship of innovation on standardization.

4.5.2 Standards and the Incentive to Invest in Innovation

4.5.2.1 Theoretical Predictions

As already mentioned for a long time standards have been deemed to lower innovation incentives because standards are meant to fix a certain technology as standard whereas innovation is intended to create something new (Mangiarotti and Rillo 2014). In recent years, however, it has increasingly been emphasized that standardization and standards can also be seen as an important mechanism for stimulating innovation. The impact of standards on firms' incentive to invest in innovation has mainly been analyzed in theoretical approaches. Most of the analysis has focused on investments in subsequent follow-on innovations (Blind 2013) whereas fewer approaches have investigated the effect on the ex-ante incentive to invest in innovation (Aoki and Schiff 2014).

From a theoretical point of view, the relationship between standards and innovation is ambiguous. Standards can hinder or stimulate innovation (Swann 2000, 2010). Blind (2013) argued that the effect of standards on innovation also depends on the type of standards. He summarized 4 types of standards and their potential positive and negative effect on innovation (see Table 1).

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As explained in section 4.4. one important function of standards is to improve and ensure compatibility and interoperability between components of products and services that are independently supplied component technologies (Rysman and Simcoe 2008). Compatibility between products might also generate positive network externalities among users (Blind and Gauch 2009). Both compatibility and interoperability might stimulate innovation via different but related channels. First this type of coordination decreases transaction costs (David and Greenstein 1990, Blind and Gauch 2009), facilitates trade and fosters the diffusion of new technologies especially in network industries. It might lead to a bandwagon process among adopters and might alleviate hold-up problems by promoting "open" technology (Besen and Farrell 1991, Farrell and Saloner 1988). Katz and Shapiro (1985) study the effect of compatibility (standards) in markets with network externalities. They show that the level of total output is greater under industrywide compatibility than under incomplete compatibility. Furthermore, under reasonable conditions firms in the standard can increase their output whereas the average output of firms not in the standard will fall. Realizing greater output we expect benefits to rise as well. This should provide firms with additional financial means for follow-on innovations. Second, standards ensuring compatibility and interoperability might also alleviate lock-in effects to old technologies if compatibility between old and new technologies is ensured (Blind (2013). This increases the incentives to invest in follow-on and next-generation technologies. Katz and Shapiro (1992) for example analyzed the introduction of a new product in a market with network externalities. Contrary to the wide-spread believe that such markets are locked-in in existing products and technologies, their analysis reveals that under certain conditions there is tendency to rush into new technologies. However, analyzing the firm's incentive to make the new product compatible, they find that the innovating firm is biased against compatibility and favors the development of new incompatible technologies. Third, coordination through standardization improves furthermore the incentives and abilities to develop, produce and sell complementary goods (Chiao et al. 2007). Fourth, compatibility and interoperability also improves efficiency in the supply chain. This lowers the costs for producing new products and increases expected profits from innovation so that firms are more likely to invest in innovation. And finally, compatibility and interoperability might increase competition both between and within technologies which might stimulate the incentives to innovate as well (Arrow 1962, Aghion et al 2005). On the other hand, standards are an essential component of firms' infrastructure which builds the basis for subsequent innovations (Blind 2013). Hence, standards might create lock-in effects in old technologies especially in case of strong network externalities and thus lower the incentive to innovate. Katz and Shapiro (1992) show that this leads to a delay in radical innovation.

In recent years it has furthermore increasingly been emphasized that standardization and standards fulfill an important information function and can be seen as an important mechanism for knowledge transfer. Research activities produce knowledge which can be partly codified in publications, patents and other forms of codified content, e.g. databases. Besides codified knowledge, research activities generate tacit knowledge in the researchers. In the course of the standardization process the actors involved – characterized by having heterogeneous backgrounds, capacities and knowledge – interact with each and often exchange *tacit* knowledge about research results, technical specifications and technical solutions. This is particularly relevant in emerging

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technologies (Blind and Gauch 2009). And product and technical standards – as outcome of the standardization process – themselves provide *codified* knowledge that reveals relevant technical information on the preferred technology or technical specification. Standards are thus seen as a mean to disseminate research results and diffuse the state of the art in science and technology and best practice. Since many firms are engaged in research projects that deal with interoperability of technologies they need state-of-the-art information on standards that are available or that are under development. In contrast to patents, standards are accessible to all actors in industry, research institutes, public sector and society at low costs. Furthermore, they are more likely to be broadly implemented as all interested stakeholder have agreed upon the technical specifications within a consensus process (Blind 2013). Improving the access to external knowledge, firms might absorb and integrate this external knowledge into own research and innovation activities (Cohen and Levinthal 1990). Standards can also facilitate future networking with other researchers, industries and stakeholder. Altogether, this suggests that standards might play an important role in stimulating follow-up innovation activities (Blind 2013). But on the other hand, standard can lead to a free riding problem if a firm free-rides on research results by other firms. This might lower the marginal incentives for own R&D investment and hence reduces innovation (Cabral and Salant 2014).

Minimum quality and safety requirement or measurement and testing standards help an innovative firm lowering information asymmetries between itself and its customers about the quality of the new product or technology. It also alleviates the problem of adverse selection. New products or technologies might be associated with higher risks related to safety, health and environmental issues. With complying with safety requirements, for instance, firms do not deliberately offer new products that later turn out to have inacceptable safety risks. Overall, these types of standards help innovative firms to create trust. They can demonstrate to the customers that their innovative products possess the features they claim to have and have acceptable levels of risks for health, safety and environment. This increases expected demand and profits from innovation and hence raises the incentive to innovate in the first place. As such they are particularly important in the market introduction phase of the innovation process Blind (2013). But, complying with certain minimum (high) quality and safety standards and measurement and testing procedures might also raise the overall costs of developing new products which in isolation lowers the incentive to innovate and thus acts as a barrier to innovation.

As explained in section 4.3. the implementation of standards might lead to a reduction in variety. By limiting the number of options standards lead to focusing on specific technologies. As a result firms might realize larger economies of scale. By lowering production costs firms generate higher profits which should increase both the ex-ante incentive to invest in innovation and the investments in follow-on innovation due to larger financial means. Variety reduction might be particularly important for emerging technologies and industries. In this case, reducing the number of options might help to achieve a critical mass necessary for establishing the emerging technology and to promote the development of complementary technologies (Blind 2013). The selection and prioritization of knowledge and technologies associated with variety reduction also leads to a bundling of resources and might lower the problem of fragmentation of ownership rights (Blind

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and Gauch 2009), again this might be particularly relevant for emerging technologies. But on the other hand, a reduction in the choice set might also lower innovation incentives for developing a better next-generation technology. In many cases standards are formed at an early stage of the technology evolution. For these emerging technologies there often exist a variety of promising alternatives though the virtues of each of them is uncertain at this early stage (Chiao et al 2007). Hence, in emerging technologies and industries there is the special risk of lock-in effects in a premature technology that might become inferior over time. Furthermore, it might lead to a stronger market concentration which above a certain threshold has been found to lower innovation incentives (Aghion et al. 2005).

Table 1 Potential Effects of Standards on Innovation

Standardization	Effects of Standards on Innovation	
Type / Function	**Positive Effects**	**Negative Effects**
Compatibility / Interoperability standards	• Forster diffusion of new technologies especially in network industries (network externalities) • Avoiding lock-in to old technologies • Increasing incentives to develop complementary products • Efficiency in supply chains • Enable competition between and within technologies	• Monopoly power • Lock-in in old technologies in case of strong network externalities
Minimum Quality / Safety / Measurement Standards	• Reduction of information asymmetries • Avoiding adverse selection • Creating trust • Reducing transaction costs	• Raising costs for developing new products
Variety Reduction	• Generating economies of scale • Critical mass in emerging technologies and industries	• Reducing choice • Market concentration • Premature selection of technologies
Information	• Providing codified knowledge and diffuse state of the art in science and technology	• Free-riding on rivals' research efforts

Source: Own representatation, based on Blind (2013) and Swann (2000).

Blind and Gauch (2009) and Blind (2013) additionally investigate the role of different types of standards in the *innovation process* (see Figure 5). Standards can be an important source of knowledge by reducing information costs and transaction costs for subsequent research. Terminology and classification standards are especially important for basic research, measurement

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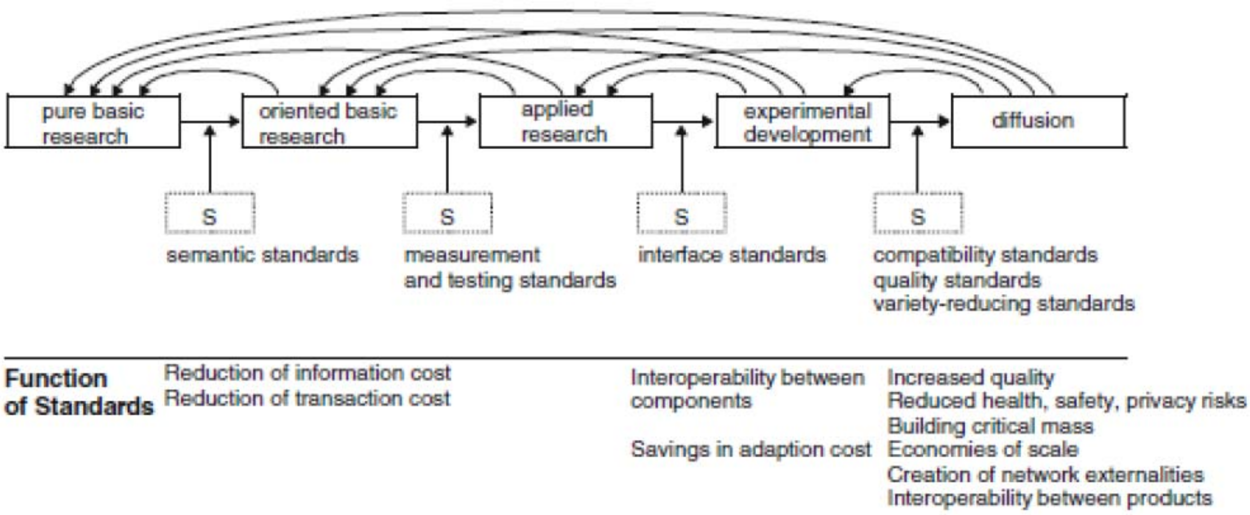
and testing standards in applied research. Interface standards which ensure interoperability between components and reduce adaption costs are particularly relevant for the experimental development phase. Quality, health and safety standards are crucial for the market introduction by restricting possible risks of innovative products and technologies. Finally, compatibility standards can generate economies of scale, critical mass, interoperability between products and network externalities. Hence they are important for the diffusion of technologies and products especially in network industries Blind (2013).

Figure 5 Functions of Standards in the Innovation Process



Source: Blind and Gauch (2009)

The recent model by Aoki and Arai (2013) specifically provides a theoretical framework for analyzing innovation and standards over the technology life cycle. Their model is based on Farrell and Saloner (1985) but most importantly they endogenize the decision to invest in innovation. The basic assumption is that there is already a standard in place. They furthermore have two types of firms in their model, the incumbent which is the current standard technology owner and the entrant. The incumbent can decide to invest in two things. He can decide to improve the current standard technology (upgrade) which always makes consumer better-off or to invest in complementary technologies and products (installed base). The latter investment increases inertia in their model due to increasing switching costs. In the model of Aoki and Arai (2013), the entrant can only invest in improving the standard. Their model shows that effect of standards on innovation incentives depend on the technology life cycle. When technology is in its infancy and the returns from investment are high, the incumbent will invest in improving the standard (upgrading) which always makes consumer better-off and in complementary products which also raises switching costs. Both investments deter entry at this early stage of technology evolution and a single standard exists. But when the technology matures, the incumbent will allow entry leading to the co-existence of two – new and old – standards. However, there will never be replacement in equilibrium which means that the entrant never dominates. Given that standards affect innovation

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differently for infant and mature technologies, Aoki and Arai (2013) concludes that competition and standardization policy should be technology life cycle dependent.

While all the previous arguments implicitly assumed a standard that is based a consensus of participating firms, Jensen and Thursby (1996) examine the effect of an anticipatory product standard. For instance governments might implement anticipatory product standards in order to improve the strategic position of firms in an international patent race where firms do R&D to develop products that are close substitutes. Their results show that the use of these anticipatory standards is problematic in dynamic and uncertain environments. Most importantly for policy, the effect of standards on innovation depends on which firm develops which product and on the order in which products are discovered. They show that under these circumstances it is more likely that both firms will race to develop the *same* patent. But even when the foreign and domestic firms still pursue different patents strategies, they reveal that simple anticipatory standards are time inconsistent. That is, even if a standard certainly increases welfare after all products are discovered, it still can reduce ex ante expected welfare. This is due to the consumer loss when products are discovered but ruled out by a simple standard before the product that is set as the standard is discovered. Hence the only anticipatory standard which can unambiguously increase welfare is a state-contingent standard. A state contingent standard is shown to be time consistent when compulsory licensing by the foreign firm is introduced.
That is, expected welfare can still be lower because the

4.5.2.2 Empirical Findings

Empirical studies on the effects of standards on innovation are still scarce and also diverse in methodology. But nevertheless most of the recent empirical studies on innovation so far have corroborated that standards play a positive role for innovation.

Swann and Lambert (2010) studied the question whether standards enable or hinder innovation using data from the UK Community Innovation Survey (CIS). They exploit two questions from the CIS. First whether technical, industry or service standards have been used as an information source for innovation activities and second whether UK/EU regulations were an important barrier for innovation. The descriptively show a positive correlation between both answer. That is 52% of the firms said that standards were a source of information for innovation activities. Among them the majority (75%) also perceive regulations to constraint innovation. On the other hand, among those firms which do not use standards for knowledge sourcing, the majority (63%) perceives no innovation barriers due to regulations. They furthermore show that for those firms that are simultaneously use standards as information source and perceive regulations as barrier, are more innovative.

Blind et al (2010) used quantified expert opinions to study the impact of international ICT standards on innovation using quantified expert opinions. They find that ICT standards stimulate innovation in particular in three dimensions: product variety, degree and speed of adoption of new products and services. Using a case study approach Michel (2012) studied the impact of standards

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on innovation in the charging infrastructure for electric vehicles in the Netherlands. He found that innovation was particularly stimulated by the fact that the standardization process was characterized by avoiding technological lock-ins and enabling competition. That is standards ensured compatibility between different charging stations and service providers which is necessary to execute a market model that involves a multitude of firms competing with each other.

Econometric evidence is for instance given in Blind (2004) and Konrad and Zlyczysti (2010). Both studied the effect of standards on innovation at the firm level for German firms. Konrad and Zlyczysti (2010) find a positive correlation between patenting and standards in German industries which cannot necessarily be seen as causal inference. Blind (2004) additionally perform Granger causality tests and find a weak positive impact of the stock of standards on patents.

Baron et al (2014) econometrically investigate the role consortia play for the standardization process and innovation. The development of formal standards is challenging since different firms develop proprietary innovation ahead of the standardization process without any ex ante contracting between SSO members. Hence finding a consensus among SSO members is challenging given the R&D rivalry among members. As a result coordination failure might arise in form of R&D duplication and delays (Farrell and Simcoe 2012 and Simcoe 2012). In order to better align positions on a common technology some firms may create a consortium, some of them accompany a formal standardization process but some are substitutive. The main aims of a consortium are to enhance R&D coordination, increase the influence in SS processes (Leiponen 2008) and to obtain essential patents (Pohlmann and Blind 2012). Delcamp and Leiponen (2012) found that joining a consortium connected with 3GPP increases cross-citations between the members' patents. Baron et al (2014) investigate whether consortia can effectively alleviate R&D coordination failure in SSO through enhanced ex ante R&D cooperation. They assume that SSO may be oriented towards two different coordination failure regimes: public good and rent seeking regime. The regimes are characterized by the firms' incentives to contribute proprietary technology which depend on the share of the standard's value (profits) that accrue to owners of essential patents. In rent seeking regimes licensing revenues are sufficient to cover R&D costs. In a public good regime, however, firm's incentive to innovate is primarily driven by expected sales of standard-compliant products. They theoretically show that both regimes induce opposite effects on consortia on firms' R&D investment. In a strong public good regimes building a consortium leads to an increase in R&D of consortium members while R&D decreases under a rent seeking regime. The latter can mitigate coordination failure at SSO level. To test the hypothesis they use a large panel of 167 ICT standards over 9 years and 21 closely related consortia. A rent-seeking regime is identified by the proportion of pure R&D firms in the consortium. Pure R&D firms should only be present in rent seeking regimes since they can only profitably take part in standards development when licensing revenues exceed R&D costs. Their empirical analysis corroborates that the decision to join a consortium positively affects own firm-level patenting (targeting the standard) under a public good regime while it is negatively correlated under a rent seeking regime. In a strong public goods regime innovation would increase by 30% while it decreases by 68% in a strong rent-seeking system and no effect on innovation in the intermediate case. Second, they

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assess the effect of consortium membership on the patent output of other firms contributing to the same standard. The entry of a new member in the consortium leads to more (less) innovation by the new member in a public goods regime (rent seeking regime) and more (less) innovation by the other consortium members in a public goods regime (rent seeking regime). Furthermore, overall innovation increases after a firm joined a consortium. However, this effect is significantly weakened or even reversed as the participation of pure R&D firms in SS increases, i.e. for standards characterized by a strong rent seeking regime. To sum up, there study shows that consortia can unlock (increase) innovation in SS processes but in some cases also mitigate intensive patenting around the standard when it is wasteful for firms.

Using a mixture of expert opinions from 7 case studies and calibrations, Scott and Scott (2015) study the impact of measurement and technical standards on investments in industrial R&D and on private and social benefit-to-cost ratios. Both standards have value-shifting and probability distribution-shifting effects for the firm making innovative investments. They develop a simple model in which the relative quality *x* of a company's technology (relative to competitors in post-innovation market) depends on firm's and rivals research efforts. The uncertainty of the technical success of both efforts is reflected in probability distribution of *x*. In the post-innovation market, the higher the firm's relative quality, the more competitive it is and the higher the present expected value of future profits V(x). Firm chooses its research effort to maximize the net present value NPV=V(x)-wR with wR being the cost of research effort. This model is calibrated in the following way. They use survey information in which firms should estimate by how much their own and rivals research input would change in a situation in which (1) public laboratories and the infrastructure technology they provide are absent from SSO and (2) in which no product standards exist. In the first counterfactual scenario the R&D effort needed to achieve a given expected quality index would be 25% higher and the net present value falls (distribution-shifting effect). In addition, the value in post-innovation market would be 10 % lower because of what the standards are doing for production and commercialization. This effect reduces optimal R&D effort and reducing NPV (value-shifting effect). Based on the survey the value-reducing effect more than offsets the distribution-shifting effect and R&D investment would decrease by 64.4%. In the second counterfactual situation firms estimated that the R&D effort required to achieve a given R&D quality index would on average increase by 50% and that the value of R&D outcomes would decrease by 30%. Taking the net effect of distribution-shifting and value-shifting effects this would lead to a decrease of R&D by 93% of what it would be with SSO. In a final step respondents were asked to approximate the proportion of their typical research project's total value that would not be captured by their firm but would spill over to other firms (producer surplus) and customers (consumer surplus) under both scenarios. For scenario 1 without public laboratory support they finally estimate that R&D investment falls by 8.3%, the private benefit-to-cost-ration falls by 13.8% and the social benefit-to-private-cost ratio falls by 32.5%. For scenario 2 without product standards, R&D investment falls by 34.5%, the private benefit-to-cost-ration falls by 19.1% and the social benefit-to-private-cost ratio falls by 59.1%. This shows that standards have a large impact on the private and social value of industrial research.

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4.5.3 Role of Rules and Procedures at SSO and Innovation

The EU commitment 16 on standardization aims at fostering standardization as well as modernizing and speeding up the standardization processes in Europe. The previous section has investigated the role standards play for innovation in general. This section particularly focusses on whether (1) standard setting organizations (SSO) in general and (2) the rules and procedures they apply might impact innovation as well. For answering this question it is important to keep in mind that several SSOs exist which compete against each other because one can have multiple technological approaches to the same problem. In addition, competition with other standard-setting efforts within the same organization might exist (Chiao et al. 2007).

Importance of SSO for Innovation

The literature has mainly seen SSO as a forum where competitors can resolve conflicts (Chiao et al. 2007). Farrell and Saloner (1988) for example study the case where two firms (technology sponsors) offer two incompatible technologies. Each firm favors its own technology to be selected and has private information about its quality. They can solve this problem by repeatedly talking to each other at SSO meetings, through product market competition or through a hybrid model. Farrell and Saloner (1988) first modeled consensus standard setting as a war of attrition. That means that when the consensus principle at SSO enables each participant to hold up an agreement, and side-payments or compromise are unavailable or ineffective, bargaining becomes a war of attrition (Farrell and Simcoe 2012). They show that the SS process is more likely to lead to a higher-value consensus than product market competition but it usually takes longer. The hybrid approach generally dominates both alternatives. Bulow and Klemperer (1999) generalized this to multiple firms. Though the SSO is the place where both firms negotiate, this model does not include any institutional features (decision making rules, disclosure rules etc.). As institutional features do not matter, there is no need to allow for more than one SSO (Chiao et al. 2007).

Empirically, evidence for the importance of SSOs is provided by Rysman and Simcoe (2008). More specifically they investigate whether voluntary standards increase the value of a technology by creating a consensus and providing a path to industry coordination. They analyze the flow of citations to a sample of U.S. patents disclosed during SS processes. They identify a sample of 724 US patents disclosed at four major SSO: American National Standards Institute (ANSI), Institute for Electrical and Electronic Engineers (IEEE), Internet Engineering Task Force (IETF), International Telecommunications Union (ITU). Identifying the effect of standards of the value of technology is challenging as there are two effects at work. First, there might be a selection effect in a sense that the SSO identifies and attracts technologies that are more significant or about to become so and as a result they receive more citations. Second, there might be a marginal effect of disclose and consensus. By fostering consensus and creating an open standard, the SSO causes firms – those that do and do not contribute IP to the standard – to adopt and use a patented technology which they potentially would not have used without the standard. This in turn might change the citation profiles of both standard-essential patents and non-standard patents. In order to identify the marginal effect they have to estimate a counterfactual situation. They identify the impact of disclosure by within-patent changes in citation frequency around the time of disclosure of

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standard-essential patents and the set of control patents from the same technological field and application year.

Their empirical analysis reveal two key insights: First, *SSO patents are cited substantially more frequently after standardization* than the control patents. Pre-disclosure the citation rate of SSO patents is roughly twice as large as that of the average patent. Depending on the model, disclosure leads to a further 19%-47% increase in citations of SSO patents. Assuming that the time of disclosure is exogenous, this can be interpreted as the causal effect of SSO endorsement and subsequent technology adoption. Second, the *age distribution of SSO patent citations is shifted toward later years* relative to an average patent. That is these citations are less concentrated in the first few years after issuing the patent and SSO patents receive citations for a much longer period of time. Both findings suggest that SSO patents have a longer than average useful life.

Importance of rules and procedures at SSOs for Innovation

According to Lemley (2002) important features of SSO relate to their search, disclosure and licensing rules. Most SSO – 27 out of 36 in Lemley (2002) – require that members disclose any known IPR as soon as possible. Disclosure in general means a letter declaring that a company owns or may own IP relevant to a proposed standard, with great detail in variety. Some disclosures refer to specific patents and contain licensing terms while others are simply general statements regarding firm's willingness to license the patent (Rysman and Simcoe 2008). An important question is to what extent this rule of SSOs is enforceable. If the disclosure commitment a firm makes in SS processes is not binding, the value of such commitment would be very low and the risk is high that the firm deviates. A firm might have the incentive not to disclose its IPR during the SSO process and subsequently try to license the protected technology demanding higher royalty fees. In general, enforceability of this rule is high as for example the legal principle of equitable estoppel protects one party from being harmed by another party's voluntary conduct (action, silence, acquiescence or concealment of material facts). Only a minority of SSO – 2 out of 36 in Lemley (2002) – demand a full patent search of their members.

Chiao et al. (2007) argued that it is also important to distinguishing between traditional SSO which are generally open to all interested parties and often have detailed cumbersome procedures and special-interest groups which are often small, invitation-only bodies and more likely to be dominated by technology sponsors. Despite the lower pace of finding a consensus and establishing a standard in traditional SSO, they generally provide a more effective stamp of approval (Chiao et al. 2007).

Instead of focusing on SSO as a forum for reaching consensus, Lerner and Tirole (2006) investigate the role of SSO as certifier rather and analyze forum shopping by technology sponsors. The basic assumption is that there is competition between SSO and that the SSO differ in their degree of sympathy for technology sponsor relative to end-users. A sponsor of an attractive technology can afford to make a few concessions – such as royalty-free licensing – to prospect users. It will choose the SSO that is relatively friendly to his case and whose certification will persuade end-users to adopt the standard. Their model predicts (i) a negative relationship ship between the extent to which an SSO is oriented to technology sponsors and the concession level required of sponsors

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and (ii) a positive relationship between sponsor friendliness of selected SSO and the quality of the standard.

Chiao et al. (2007) extend the model by Lerner and Tirole and empirically examine differences between rules and operations of different SSOs. Understanding the working of SSOs is important because it can have a profound impact for instance on the abilities of innovators to coordinate and on the incentives to innovate. They analyze the relationship between organizations' characteristics and their policies concerning the disclosure and licensing of IP based on a sample of nearly 60 SSO. Their analysis reveals the following four key findings. First, the presence of provisions mandating royalty-free licensing is *negatively* associated with disclosure requirements, i.e. higher licensing prices should be associated with more disclosure. Second, the relationship between the concession level of sponsors and the user friendliness of SSO is weaker when there is only a limited number of SSO. *Sponsor*-friendly SSO may demand substantial concessions to attract weak standards. By contrast *user*-friendly SSO may make weak demands so as to appeal to sponsors with stronger technologies. Third, there is a *positive* correlation between sponsor friendliness of selected SSO and the quality of the standards as predicted by Lerner and Tirole (2006). The latter is measured as maturity of the technology subfield in which the standard is located which is used as proxy for attractiveness. Fourth, the empirical evidence is likewise consistent with the theoretical prediction of Lerner and Tirole (2006) showing a *negative* correlation between the extent to which an SSO is oriented to technology sponsors and the concession level required for sponsors.

4.5.4 Standardization and IPR Strategies

By far, not all standards are related to IPRs like patents. Patents are particularly important in standards in those areas where standards relate to innovative and therefore often patented technologies, like ICT (Blind 2011). It is observed that patents play an increasingly important role in the standard setting process at many SSO. In particular this is a big issue in ICT standardization and its increasing importance partly reflects a well-documented surge in patenting in particular in ICT industries from the mid 1980s (Rysman and Simcoe 2008). Many firms would like to own patents that are part of an industry standard. A patent is called a standard-essential patent (SEP) when it is not possible on technical grounds to make or operate equipment or methods which comply with a standard without infringing the patent. As already mentioned most SSO require that their members declare during the proposal or development of a standard that they hold standard-relevant patents. All European SSO and their international counterparts ISO, IEC, ITU-T require SEP declaration under FRAND conditions; that is that the patent owner is willing to grant irrevocable licenses on fair, reasonable and non-discriminatory ("FRAND") terms and conditions. However, it often remains vague how FRAND is defined in practice (Blind 2013).

Blind (2013) summarizes the main benefits and cost of integrating patents in standards. On the benefit side SEP are likely to generate a steady stream of licensing revenue in future years and if a standard also demands backward compatibility they can even generate ongoing licensing revenues for outdated products. This continuous stream of licensing revenues might create additional

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incentives to invest in R&D. Standards involving SEPs are often accompanied by patent pools (see the following section in more detail). Creating patent pools furthermore reduces transaction costs for both patent owner and standard adopter (Bekkers et al 2012). But they also generate additional licensing for the former due to the diffusion effect of standards and reduce licensing costs for the adopter. The latter can be explained by avoiding double-marginalization which reduces the price for the whole bundle of licensing necessary for the implementation of the standard (Blind 2013).

Costs of integrating patents in standards include the risk of cementing temporary monopoly to permanent monopoly which restricts competition and further innovation (Blind 2013). These monopolies might even survive the date of patent expiration which creates long-term inefficiencies by higher prices and lower competition. Such dominant positions might also promote lock-in effect into inferior outdated technologies.

Standardization might also change IPR strategies of firms as was shown by Simcoe et al (2009). They compare the IP strategies of small entrepreneurs and large incumbents that have disclosed patents at 13 voluntary standard setting organizations (SSOs). Entrepreneurs often rely on IPRs to earn a return on their innovations, and on compatibility standards which allow them to supply specialized components for a shared technology platform. Patents disclosed to SSOs have a relatively high litigation rate. Their findings show that small private firms are more likely to file a lawsuit and thus to litigate after disclosure of patents to the SSO while there is no change in behavior of large public firms. This is even more surprising as the increase in the relevant value of their patents (measured by forward citations) after disclosure is the same for small entrepreneurs and large incumbents. These results suggest that standards increase the difference between large and small firms' incentives to litigate, rather than the relative value of their patents. This indicates that small specialized technology providers cannot seek rents in complementary markets and as a last resort they defend IP more aggressively once it has been incorporated into a standard.

4.5.5 Standards, Patent Pools and Innovation

In particular technology standards are increasingly the result of collaborations among a large number of market players (Chiao et al. 2007, Farrell and Simcoe 2012, Vakili 2015). Since many of these technology standards involve complementary IPRs like patents this leads to standards with fragmented ownership rights (Shapiro 2001). This ownership fragmentation leads to high searching, negotiation and licensing costs when another firm would like to adopt the standard (Shapiro 2001, Lemley and Shapiro 2007). Licensing costs are high because each partial patent owner maximizes its own profit not taking externalities due to complementary into account (Merges 1999, Shaprio 2001). High searching costs exists because it is difficult to identify all relevant patents required for implementing the (standardized) technology. Summing up all the costs for all the individual licenses necessary to adopt the technology might easily lead to a situation in which the costs exceeds the expected benefits so that a potential adopter refrains from licensing. The fragmentation of ownership of complementary patents creates an additional problem for firms contributing with their IPR to the standard as any pricing, marketing or network

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strategy could be rendered ineffective if there is no coordination among the partial owners of the standard-relevant IPRs (Vakili 2015). This can prevent firms from investing in promotional strategies and highlights the importance of coordination (Shapiro 2001).

In order to prevent an underutilization of such fragmented technology standards, many firms form patent pools. A patent pool is a voluntary organization that pools a group of patents into a single licensing package. The pool members agree to collectively license the included patents to one another or to third parties. It can be seen as a collaborative platform to promote the adoption of fragmented technology standards (Vakili 2015). Prominent examples of patent pools include DVD, 3G, MPEG or SARS. In 1995 the Department of Justice and Federal Trade Commission acknowledged a pro-competitive effect of patent pools of complementary patents. That is, by internalizing pricing externalities patent pools avoid double-marginalization (royalty stacking) associated with independent licensing and as a result reduce licensing royalties. It furthermore reduces transaction costs of negotiations. Lower licensing royalties and transaction costs are pro-competitive and welfare-enhancing. From that time onwards patent pools have become an emerging tool for overcoming fragmented, overlapping and blocking patent rights (Layne-Farrar and Lerner 2011). The creation of patent pools is not necessarily tied to standards and standard-essential patents but nevertheless modern patent pools are largely spawned by standard setting efforts (Layne-Farrar and Lerner 2011). This implies that generally patents protect distinct features of the technology and need to be used together to implement the standard. Thus, most patent pools consist of complementary patents. The decision of whether a patent is included in a patent pool is generally made by an independent expert for review who assesses essentiality of the patent according to member defined criteria. (Layne-Farrar and Lerner 2011).

An important issue in forming a patent pool is the decision upon the royalty fees and the licensing sharing rule. In general, the pool members collectively set the royalty fees that they charge for the full patent package. With respect to sharing rules of license earnings, mainly three sharing rules are applied in practice. First, pools can decide to license the patent package free of any royalties which implies that there are no royalties to share. Firms might opt for a *royalty-free rule* when they want to promote a technology for which they offer revenue-generating complementary products or services which benefit from a wide diffusion of the technology (Layne-Farrar and Lerner 2011). Second, a patent pool can decide upon a *numeric proportional rules*. This implies that patent owners receive a share of the aggregate licensing earnings that is based on the number of patents they contribute to the pool. In contrast, a *value proportional sharing rule* distributes a larger share of the licensing earnings to patent owners with more valuable patents. Layne-Farrar et al (2007) stressed that even among standard-essential patents the value of a patent's contribution can substantially vary. This depends on the associated technology component and the availability of alternative technologies. Though economically more valuable patents should earn higher royalty payments most patent pools opt for a numeric proportional rule since they are easier to administer (Layne-Farrar and Lerner 2011). But note that most patent pools with complementary patents additionally allow their members to independently license their patent outside the pool (Lerner and Tirole 2008, Layne-Farrar and Lerner 2011).

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Patent pools have been mainly analyzed theoretically and much of the analysis has focused on their role in competition policy like their impact on pricing behavior (e.g. Choi 2003, Lerner and Tirole 2004, Teece and Sherry 2003, Gilbert 2004, Lerner et al. 2007, Lerner and Tirole 2008, see also the literature review of Deliverable 5.1). Another emerging strand of literature deals with the links between IPRs and their association with standards and patent pools (e.g. Lerner et al. 2007). Only a few studies have investigated the role innovation might play for joining a patent pool and as well the impact patent pools have on follow-on innovation.

4.5.5.1 Innovation and Patent Pool Participation

With respect to the first question, Lerner and Tirole (2004) theoretically analyzed the strategic incentives to *form a pool* in the presence of current and future innovations that either compete with or are complements to the patents in the pool. They show that the possibility to independently license patents outside the pool matters for pool formation if and only if the pool is otherwise welfare reducing. Aoki and Nagaoka (2005) also theoretically investigated a *firm's incentive to join a patent pool*. Joining a patent pool is a voluntary decision. They consider three types of firms: vertically integrated firms that conduct R&D and manufacture downstream goods, research-only and manufacturing-only firms. An important criterion for joining a pool is the distribution of licensing earnings. Their model assumes that licensing earnings are divided evenly among members. They show that firms with different business models have different incentives to join patent pools. Vertically integrated firms are more likely to join a patent pool since they benefit from patent pools in two ways. First, a patent pool of complementary patents generally charges lower aggregate license fees and reduces transaction costs of obtaining cross-licenses that these firms need to manufacture goods. Second, they benefit from the royalties they earn through the pool as patent holder. Furthermore, compared to an individual licensing (which might yield higher single returns) patent pools might provide a more widespread licensing (Layne-Farrar and Lerner 2011). Aoki and Nagaoka (2005) also show that vertically integrated firms and manufacturing-only firms always favor lowest possible royalty fees in order to reduce own production costs. On the contrary, research-only firms benefit only from licensing earnings and its profits are increasing with higher royalty rates (up to a certain threshold above which profits decline due to lower demand). As a result it favors high royalty fees. If they can negotiate higher royalty payments outside the pool, there is no incentive for them to join. This is particularly true for firms that possess very valuable patents. Under an equal rent division, Aoki and Nagaoka (2005) show that the R&D-only firm has the incentive to deviate from a patent pool because the rule does not acknowledge differences in business models compared to the other two types of firms. They therefore conclude that research firms in the pool should get an extra royalty to compensate for the lack of production profits. They model further shows that royalty rules that provide members with equal shares of total earnings lead to an underinvestment in R&D compared to the social optimum.

Empirically there is not much evidence about which factors in general drive firms' decision to form and join patents pools and whether innovation matters. One exception is Layne-Farrar and Lerner (2011) who have studied the *decision to participate in a patent pool*. One problem in order to analyze the participation decision consists of identifying the group of eligible members. Their

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population of patents eligible for pool membership consists of all patents declared to the SSO as potentially essential for implementing the standard. Across different patent pools, 30% to 60% of these eligible patents are actually included in the patent pool.[22] Endogeneity is another severe concern for the empirical analysis. Since sharing rules are defined by the founding members, both sharing rule and participation choice is simultaneously decided. In order to alleviate these endogeneity concerns they only study the effect of the sharing rule on participation among firms who join an already existing patent pool for whom the sharing rule is exogenous. Consistent with Aoki and Nagaoka (2005) they find that a *firm's business model* is an important driver for participating in patent pools. Firms that are vertically integrated which means that they conduct research and downstream manufacture a product dependent on the standard are more likely to join a patent pool. They also show that the *sharing rule* adopted by a pool significantly impacts the likelihood of joining a patent pool (see also Lerner and Tirole 2008). Theoretically they expect participation rates to be lowest for royalty-free rules which they actually could not test due to an insufficient number of pools that use this sharing rule. But they corroborate that the likelihood of joining a pool that adopts numeric proportional sharing rules is significantly lower than for pools with value-based rules. Numeric proportional rules attract more vertically integrated firms whereas R&D oriented firms favor value-based rules. Finally they also show that the *value of innovation* affects participation. The value of innovation is captured by the quality of patents that are eligible for contributing to the pool and the quality of patents is measured by the firm's average number of claims per patent. They find that patent quality raises the likelihood of joining a patent pool though this effect is weak and vanishes when the authors additionally control for the sharing rule. While the evidence for the level of patent quality per se is weak the distribution of patent quality significantly matters for participation. When patent contributions to a standard are relatively symmetric in value across firms (measured by the firm's average number of claims per patent divided by the standard's average number of claims per patent), firms are more likely to join a patent pool and they appear to be more likely to accept numeric patent sharing rules for dividing earnings since numeric rules roughly coincide with value rules while having lower transactions costs.

4.5.5.2 Effect of Patent Pools on Follow-on Innovations

The literature exploring the question whether and to what extent patent pools affect follow-on innovations is also still scarce and the theoretical predictions are ambiguous. On the other hand, Merges (1999) and Shapiro (2001) argued that modern patent pools with complementary patents are likely to encourage follow-on innovation because they lower the costs (i.e. lower royalty fees

[22] Layne-Farrar and Lerner (2011) stress that not joining a patent pool does not necessarily imply the existence of a patent holdup problem. A holdup problem exists if a patent owner exploits the essentiality of its patent for implementing a standard by seeking compensation that exceeds the patent's marginal contribution to the standard (Shapiro 2001). Firms might refrain from joining a standard because of minimal contributions to the standard, no intention of actively seeking licensing fees, existing cross-licensing with most/all other relevant patent holders or the desire to avoid close patent review by third party that could reveal weak patents or an ongoing research plan.

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and lower transaction costs) associated with adopting the (standardized) technology licensed by the pool. Patent pools might furthermore stimulate R&D investments as they reduce the risk of patent litigation (Shapiro 2001, Gilbert 2004). A more nuanced picture is given by Choi & Gerlach (2015). They theoretically examined the role of patent pools for complementary patents on follow-on innovations. They corroborate that pools with complementary patents reduce overall licensing royalties by internalizing pricing externalities and are thus pro-competitive. In a dynamic perspective, this pro-competitive effect is reinforced by the fact that these pools also stimulate follow-on innovation. As patent pools can mitigate patent thicket problem for current users, they reduce royalty rates for subsequent innovations as well which stimulates innovation. However, Choi & Gerlach (2015) also show that this conclusion does no longer hold when it is taken into account that patents are probabilistic and can be invalidated in court. When setting royalty fees, patent holders now have to consider the effect of a price increase on the demand but also the litigation incentives of potential licensees. The incentive to litigate and invalidate a patent decreases with the strength of patents. They show that with strong patents the same pro-competitive effects occur. However, when patents are weak patent pools of complementary patents can be used as a mechanism to discourage patent litigation by depriving potential licensees of the ability to selectively challenge patents and making them committed to a proposition of all-or-nothing in patent litigation. This reduced litigation risk lead patent pools to charge higher royalty rates compared to independent licensing and thus reduce the incentives for subsequent innovation. It is worthy to note that Choi and Gerlach (2015) only consider subsequent innovations of other non-pool firms but not innovation incentives of pool members.

On the other hand, the theoretical literature has argued that patent pools might lower R&D investments by pool members since the returns to R&D are shared and members may choose to free ride on other members' R&D (Vaughan 1956, Lerner et al 2007). Furthermore, the pool can soften the R&D competition among pool member leading to lower R&D investments (Lampe and Moser 2012, Shimbo et al. 2015).

Lerner and Tirole (2008) and Layne-Farrar and Lerner (2011) argue that the effect patent pools exert on the incentives for follow-on innovations depend on how pools deal with follow-on patents added to the pool. The pool can either decide to license all newly added patents without additional charge (an example is 1394 FireWire technology) or to increase royalty fees from its original licensors, in general or under certain circumstances. The DVD patent pool for example decided to leave the existing royalties unchanged unless the new member's contribution is absolutely critical. The MPEG-2 patent pool decided to leave the licensing royalties for existing patents unchanged during the term of license and to make adjustments at license renewal negotiations. Furthermore, the pool has to decide how to distribute (changed or unchanged) licensing earnings among the extended pool of patents. Members of pools with numeric proportional rules have an incentive to add new patents to the pool in order to increase the number of patents and as a result their share of licensing earnings. In order to prevent members' opportunism and hold back patents and innovations which are in the pipeline and essential for the technology licensed by the pool, the pool may require that any future patented inventions relevant to the pool's technology by pool members must be offered to the pool at no fee. This is the so called grant back policy. In this case

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the pool and its customers exclusively benefit from technological improvements while the inventor does not profit from its invention. Hence, grant-backs discourage future innovation by pool members. In addition, non-members might step in and develop technological improvements which they then either license at high fees to the pool or to its current customers (Lerner and Tirole 2008).

Empirically, Lampe and Moser (2010, 2012, 2013), Joshi and Nerkar (2011), Shimbo et al. (2015) and Vakili (2015) have analyzed how patent pools affect innovation using very different cases. Overall, empirical evidence is mixed. Lampe and Moser (2010) find that the sewing machine pool in the 19th century discouraged patenting and innovation for pool members. It furthermore diverted firm entry towards technologically inferior substitutes that did not directly compete with the pool. Lampe and Moser (2013) additionally showed that the pool was associated with a substantial rise in innovation in this technologically inferior substitute technology. Lampe and Moser (2012) exploit a window of weak enforcement (so called New Deal Policies) to identify the causal effects of patent pools on innovation for 20 industries. Under the New Deal, regulators allowed the formation of pools as they hope that this would facilitate economic recovery from the Great Depression in the 1930s. They compare changes in the total number of US patents by pool members and other firms across related technologies within the same industry that were differentially affected by the creation of the pool. This difference-in-difference approach allows them to control for changes in demand and other unobservable factors that may have influenced patenting at the industry level. Based on 75,396 patent applications across 20 industries between 1921 and 1948, their estimates show a 16 percent decline in industry-level patent applications in pool subclasses compared with control subclasses after pool formation. Joshi and Nerkar (2011) likewise find a negative impact of patent pools on follow-on innovation for the optical disk drives.

In contrast to the studies by Lampe and Moser (2010, 2012 and 2013) and Joshi and Nerkar (2011), Vakili (2015) and Shimbo et al (2015) draw a much more positive conclusion of the effect of patent pools on follow-on innovation. In contrast to Lampe and Moser (2010, 2012 and 2013), Vakili (2015) investigated the role of modern patent pools on follow-on innovations based on the pooled standards. He used data on six major modern patents pools (MPEG-2, IEEE 1394, AVC, MPEG-2 Systems, MPEG-4 Visuals, Audio MPEG and DVD 6C). Using modern matching techniques, his results show that the formation of these patent pools has raised the rate of follow-on innovations based on the pooled standards by about 15% to 22%. Follow-on innovations are measured by the number of forward citations. Moreover, he finds suggestive evidence that the establishment of modern pools spur vertical disintegration in associated industries. Upstream technology-focused firms disproportionally contribute to the development of follow-on complementary technologies and vertically-integrated firms focus on downstream application development.

In contrast to the other papers, Shimbo et al (2015) focus on both the incentives to invest in R&D for technological improvements of the current standardized technology and the incentive to develop a next-generation technology. In addition to the positive impacts of patent pools on innovation, there might be additional negative effects of patent pools on next-generation innovations. Pool members might be reluctant to invest in R&D to develop a next-generation technology because of the sunk costs associated with the current technology and the cannibalization of own rents (replacement effect, Arrow 1962). They studied the case of the optical

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disk industry and three generations of standards: CD, DVD and Blue-Ray (BD and HDDVD). They constructed a database of firms that have at least 10 US granted patents filed from 1976 to 2010 in 52 IPC classes relevant for optical disks. In total their analysis is based on 110 firms (16 licensor firms, 14 pure licensee firms and 80 non-pool members). Furthermore, they explicitly accounted for timing differences between the standard agreement and the formation of the pool for the standard. Based on panel FE estimations they identify a positive impact of standardization and patent pools on both technological improvements of current standards and next-generation innovations. More specifically, the pool formation leads to more R&D efforts by the pool licensors for improving the current standard. And both the agreement for the current standard (DVD) and the formation of the pools were followed by more R&D by the pool licensors for a next-generation standard (BD and HDDVD), relative to the non-members of the pools. The R&D of the pool licensees for the next-generation standard also increased with some lag after the pool. This suggests a positive effect of open pool licensing for their learning and innovations toward the next-generation technology. But there is suggestive evidence that sunk costs might play a role as the 6C licensors show a lower R&D response than 3C licensors presumably due to larger sunk costs.

4.5.5.3 Patent Pools and Upstream R&D Incentives

Instead of investigating the impact of patent pools on follow-on innovations, Aoki and Schiff (2014) examined the effects of patent pools of complementary patents on ex-ante incentives to invest in upstream R&D. This implies that innovation is no longer exogenously given but that they endogenize innovation. In addition they analyzed the effect of patent pools on the ex post (after upstream innovation) licensing decision. They furthermore compare how different PP licensing revenue distribution rules work and incorporate the effect of simple antitrust rules. They acknowledge that firms differ. Some firms are competitors (substitute technologies) and some firms are partners (complementary technologies). Furthermore, they investigate two scenarios: A symmetric market situation in which each firm all firms possess the same ability to develop the upstream innovation (component) and an asymmetric market in which one firm has the unique ability to develop a specific component.

They assume a four stage game: First, the antitrust rule is set and announced which means whether the PP is allowed to jointly license substitute innovations or not. In the second stage, the PP sets and announces a royalty redistribution rule consistent with the anti-trust rule. In stage three, each research firm decides to invest or not to invest in an R&D project and those that invest invent a component with given probability. In stage four, the successful inventors simultaneously decide to join or not to join the PP or license independently and royalties are paid by licensees. Note that the incentive to invest in upstream R&D is determined by ex-ante expected profits. Ex ante profits depend on the ex-post profits (probability distribution over outcomes).

Their model shows that PP can generate both ex-post and ex-ante gains and losses to welfare and profits of research firms. With respect to upstream R&D, they show that in general a *PP stimulates upstream R&D investment*. But a PP may also lower the innovation incentives of an inventor with unique ability (asymmetric ex ante market structure) because it dilutes rents. An unequal

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distribution of licensing revenue to form a PP. Furthermore, a PP that distributes licensing revenue unequally among its members is less likely to lead to welfare losses (but not always). Finally, they show that the firm's profit ranking over different PP rules differ ex-ante or ex-post and by firm (monopolistic of not). These differences are likely to lead to disagreement over PP rules and impede PP formation. Given the fact that PP rules like the revenue sharing rule affects upstream R&D investment, the innovation incentives should be taken into account when determining PP rules (Aoki and Schiff 2014).

4.6 Standards and Economic Growth

The ultimate aim of the Innovation Union is to foster smart, sustainable and inclusive growth. By triggering the diffusion of new technologies, increasing the incentives to invest in follow-on innovation and facilitating trade, standards might stimulate economic growth as well. The ability of a firm to establish its technology as an industry standard has been seen as key for its long-term competitive advantage (Hill 1997).

Empirical evidence on the effect of standards on economic growth is likewise rather scarce (see Blind 2013). In 2000, the German National Institute for Standardization investigated the impact of standards on economic growth for Germany (DIN 2000). Based on a macro model, they find that standards have increased GDP by about 0.9 percentage point for the time period between 1961 and 1996. In a follow-up study Blind et al. (2011) found a similar contribution of 0.8 percentage point for the period 1992 to 2006. Other studies using the same methodological approach for similar time periods found similar results for other countries: 0.8 percentage points in France (Miotti 2009) and Australia (Standards Australia 2006), and somewhat lower in the UK with 0.3 percentage points (DTI 2005) and Canada with 0.2 percentage points (Haimowith and Warren 2007).

Blind and Jungmittag (2008) investigated the role of standards for growth at the industry level estimating a Cobb–Douglas production function for 12 sectors in four European countries. Their results show that the growth impact of standards is technology-dependent. Standards exert the highest impact on growth in more mature, i.e. low and medium R&D-intensive sectors whereas patents are more important for growth in R&D-intensive industries.

Wakke et al. (2015) investigate the effect of *participation* in formal SSO on productivity at the firm level using a CD production function and data for 1561 German companies. Participation within formal standardization is measured by the number of committee seats at the German Institute for Standardization (DIN). Their results are mixed. For manufacturing, they find that participation is positively related to firm performance. In the service sectors, however, no such relationship is found. The also holds true if service providers' IP is protected through patents.

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4.7 Data Collection

Data bases that combine information on standards as well as innovation or patenting are hardly available. In order to empirically assess the impact of commitment 16 on standards we intend to use different data bases.

First, we will use different surveys of the Mannheim Innovation Panel which is the German contribution to the Community Innovation Surveys (CIS), see Rammer and Peters (2013). The 2011 and 2015 surveys, covering the period 2008-2010 and 2012-2014, include information on whether standards and norms act as barriers to innovation. This allows us to compare the proportion of firms that indicate standards as a hampering factors, for instance by sector and size, before and after the start of the Innovation Union. We will also correlate these indicators with innovation input and output measures

The 2009 and 2013 surveys (CIS2008 and CIS 2012), covering the period 2006-2008 and 2010-2012, includes information on whether standardization boards and documents standards have been used as source of information for innovation. This information allows us to compare the role standards play as knowledge transfer mechanism for follow-on innovation before and after the start of the Innovation Union. For CIS2012, we will also compare the German results with results for Flandern. To the best of our knowledge, this information is unfortunately not available for other European countries.

The 2009 survey (CIS2008) additionally includes information on whether the compliance with norms and standards have been the objective of innovation activities.

As a special feature the 2015 survey includes specific questions about the engagement of firms in standardization, certification and use of certificates. In particular, the survey includes information about the

- Active participation in formal standardization comittees (e.g. DIN, DKE, CEN, ETSI, ISO, IEC, ITU)
- Active participation in informal standardization consortia (e.g AUTOSAR, IEEE, IETF, W3C, ZHAGA)
- Certification of own products or services to technical norms (e.g. DIN, ISO)
- Certification of own processes, management systems, working/environmental standards (e.g. ISO9000, 14000, 50001)
- Application of technical certificates for own products (e.g. CE, GS)
- Application of certificates in the area of environment, health, employee protection for own products

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Using this information, we will more deeply analyze the role different standardization activities play for innovation activities. Unfortunately, we cannot compare this with information before the start of the Innovation Union in order to identify any changes over time.

Finally we also merged the MIP to a list of firms actively engaged in standardization activities at the German Institute for Standardization (DIN).

Most of the aforementioned data relates to German firms. We will additionally explore to what extent the disclosed standard essential patents database can be used for the assessment. It includes all disclosed IPR events at thirteen major SSOs - disclosed USPTO or EPO patents/applications are matched. In total, 46,906 disclosed patents, patent applications or blankets, from 969 different firms, with 14057 USPTO or EPO patents or patent applications are included. The development of the number of the change in SEP at European and International SSO could be used. The main drawbacks of this database relates to the fact the covered time-period ends in 2010. Furthermore, there seems to be a rather low number SEP for CEN and CENELEC. Furthermore there might be difficulties to determine the essentiality and uncertainty as to the legal validity of those patents (Dewatripont & Legros 2013).

4.8 Conclusions

This section has investigated the interrelationship between standards and innovation. From a theoretical point of view this relationship is ambiguous and depends on the type of standard under consideration. Standards may impact both ex ante innovation and follow-on innovation via different function of standards. Up to now the empirical evidence is rather scarce and much for in favor of a positive impact of standards on innovation although up to now most of the papers present correlations and not causal effects. Patent pools as a form of collective licensing also stimulates innovation. The majority of studies also found innovation to be an important driver for forming and joining standard-setting processes as well as patent pool. Finally, both theoretical and few empirical papers suggest that rules at SSO and rules of patent pools matter for innovation as well. But since the relationship between standardization and innovation is ambiguous, it is a challenge for policy makers and firms to set right framework conditions and incentives for an efficient use of standardization in order to promote innovation.

4.9 References

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P. (2005), Competition and Innovation: An Inverted-U Relationship, *Quarterly Journal of Economics* v120(2), 701-728.

Aoki, R. and Arai, Y. (2013), *Standards and Innovation: Technology vs. Installed Base*, CIS DP No.601, Tokio.

Aoki, R. and Nagaoka, S. (2004), The Consortium Standard and Patent Pools, *The Economic Review*, 55(4), 346-356.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

Aoki, R. and Schiff, A. (2014), *Patent Pools and Upstream R&D Investment*, Paper presented at 10th Evolution of Standards and Technology Workshop, Hitotsubashi University.

Arrow, K. (1962), Economic Welfare and the Allocation of Resources for Invention, in: NBER, The *Rate and Direction of Inventive Activity: Economic and Social Factors*, pp. 609-626.

Baron, J. Meniere, Y. and Pohlmann, T. (2014), Standards, Consortia and Innovation, International *Journal of Industrial Organization* 36, 22-35.

Bekkers, R. Iversen, E. and Blind, K. (2012), Emerging Ways to Address the Reemerging Conflict between Patenting and Technological Standardization, *Industrial and Corporate Change* 21(4), 901-931.

Besen, S. and Farrell, J. (1991), The Role of the ITU in Standardization: Pre-Eminence, Impotence or Rubber Stamp?, *Telecommunications Policy* 15, 311-321.

Blind, K. (2002), Driving Forces for Standardization at Standardization Development Organizations, *Applied Economics* 34(16), 1985-1998.

Blind, K. (2004), *The Economics of Standards*: Theory, Evidence, Policy. Edward Elgar, Cheltenham.

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

Blind, K. (2013), *The Impact of Standardization and Standards on Innovation*. Compendium of Evidence on the Effectiveness of Innovation Policy Intervention, Manchester Institute of Innovation Research, Manchester.

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., De Vries, H. and Wakke, P. (2010), Driving Factors of Dutch Service Companies to Participate in Formal Standardization: Cross-Sectoral and Sector-Specific Evidence, *Proceedings of the 16th EURAS Annual Standardization Conference*, 1-16.

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

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

Blind, K. and Thum, N. (2004), Interrelation between Patenting and Standardization Strategies: Empirical Evidence and Policy Implications, *Research Policy* 33, 1583-1598.

Breznitz, D. and Murphree, M. (2011), *Standardized Confusion? The Political Logic of China's Technology Standards Policy*.

Bulow, J. and Klemperer, P.D. (1999), The Generalized War of Attrition, *American Economic Review* 89, 175-189.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

Cabral, L. and Salant, D. (2014), Evolving Technologies and Standards Regulation, *International Journal of Industrial Organization* 36, 48-56.

Chiao, B., Lerner, J. and Tirole, J. (2007), The Rules of Standard-Setting Organizations: An Empirical Analysis, *RAND Journal of Economics* 38 (4), 905-930.

Chiesa V. and Toletti, G. (2003), Standard-setting Strategies in the Multimedia Sector, *International Journal of Innovation Management* 7, 281–308.

Choi, J.P. (2003), *Patent Pools and Cross-Licensing in the Shadow of Patent Litigation*, CESifo Working Paper Series No. 1070.

Choi, D.G.m Lee, H. and Sung, T. (2011), Research Profiling for "Standardization and Innovation", *Scientometrics* 88, 259-278.

Choi, J.P. and Gerlach, H. (2015), *Patent Pools, Litigation and Innovation*, CESifo Working Paper Series No. 4429.

Cohen, W. and Levinthal,D.A. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly* 35 (1), 128-152.

David and Greenstein (1990), The Economics Of Compatibility Standards: An Introduction To Recent Research, *Economics of Innovation and New Technology* 1(1-2), 3-41.

Delcamp, H. and Leiponen, A. (2012), *Innovating Standards through Informal consortia: The Case of Wireless Telecommunications*, NBER Working Paper 18179, Cambridge, Ma.

Dewatripont, M. and Legros, P. (2013), Essential Patents, FRAND Royalties and Technological Standards, *Journal of Industrial Economics* 61 (4), 913–937.

DIN (2000), *Economic Benefits of Standardization*, Beuth Verlag, Berlin.

DTI (2005), *The Empirical Economics of Standards,* DTI Economic Papers, London.

ETSI (2015), *Connected World – Annual Report 2015*.

Farrell, J. and Saloner, G. (1985), Standardization, Compatibility and Innovation, *RAND Journal of Economics* 16, 70-83.

Farrell, J. and Saloner, G. (1988), Coordination through Committees and Markets, *RAND Journal of Economics* 19(2), 235-252.

Farrell, J. and Simcoe, T. (2012), Choosing the Rules for Consensus Standardization, *RAND Journal of Economics* 43(2), 235-252.

Fischer, R. and Serra, P. (2000), Standards and Protection, *Journal of International Economics* 52, 377–400.

Gamber, T., Friedrich-Nishio, M. and Grupp, H. (2008), Science and Technology in Standardization: A Statistical Analysis of Merging Knowledge Structures, *Scientometrics* 74(1), 89-108.

Gawer and Henderson (2007), Platform Owner Entry and Innovation in Complementary Markets: Evidence from Intel, *Journal of Economics & Management Strategy* 16(1), 1-34.

Gilbert, R.J. (2004), Antritrust for Patent Pools: A Century of Policy Evolution, *Stanford Technology Law Review*.

Haimowitz, J. and Warren, J. (2007), *Economic Value of Standardization*, Standards Council of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

Canada, Ontario.

Hill, C.W.L. (1997), Establishing a Standard: Competitive Strategy and Technological Standards in Winner-Take-All Industries, *Academy of Management* 11 (2), 7-25.

ISO and IEC (2004), ISO/IEC Guide 2:2004, *Standardization and Related Activities - General Vocabulary*, 8th ed., Geneva.

ITU (2014), Understanding Patents, Competition and Standardization in an Interconnected World.

Jensen, R. and Thursby, M. (1996), Patent Races, Product Standards, and International Competition, *International Economic Review* 37(1), 21-49.

Jones, P. and Hudson, J. (1996), Signalling product quality: When is price relevant?, *Journal of Economics Behavior and Organization* 30(2), 257-266.

Joshi, A. and Nerkar, A. (2011), When Do Strategic Alliances Inhibit Innovations by Firms? Evidence from Patent Pools in the Global Optical Disc Industry, *Strategic Management Journal* 32 (11), 1139-1160.

Katz, M.L. and Shapiro, C. (1985), Network Externalities, Competition and Compatibility, *American Economic Review* 75, 424-440.

Katz, M.L. and Shapiro, C. (1992), Product Introduction with Network Externalities, *Journal of Industrial Economics* 40, 55-83.

Konrad, A. and Zlyczysti, P. (2010), Normung und Innovation sind keine Gegensätze, *Wochenbericht des DIW Berlin* 40, 10-14.

Lampe, R. and Moser, P. (2010), Do Patent Pools Encourage Innovation? Evidence from the Nineteenth-Century Sewing Machine Industry, *Journal of Economic History* 70(4), 898-920.

Lampe, R. and Moser, P. (2012), *Do Patent Pools Encourage Innovation? Evidence from 20 US Industries Under the New Deal*, NBER Working Paper 18316, Cambridge, MA.

Lampe, R. and Moser, P. (2013), Patent Pools and Innovation in Substitute Technologies – Evidence from the 19th century Sewing machine Industry, *RAND Journal of Economics* 44 (4), 757-778.

Layne-Farrar, A., Padilla, A.J. and Schmalensee, R. (2007), Pricing Patents For Licensing in Standard-Setting Organizations: Making Sense of FRAND Commitments, *Antitrust Law Journal* 74(3), 671-706.

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

Leiponen, A.E. (2008), Competing through Cooperation: The Organization of Standard Setting in Wireless Telecommunications, *Management Science* 54, 1904-1919.

Leland, H.E. (1979), Quacks, Lemons and Licensing: A Theory of Minimum Quality Standards, *Journal of Political Economy* 87(6), 1328-1346.

Lemley, M.A. (2002), Intellectual Property Rights and Standard Setting Organizations, *California Law Review* 90, 1889-1980.

Lemley, M.A. and Shapiro, C. (2007), Reply: Patent Holdip and Royalty Stacking, *Texas Law Review* 85.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

Lerner, J., Strojwas, M. and Tirole, J. (2007), The Design of Patent Pools: The Determination of Licensing Rules, *RAND Journal of Economics* 38, 610-625.

Lerner, J. and Tirole, J. (2004), Efficient Patent Pools, *American Economic Review* 94, 691-711.

Lerner, J. and Tirole, J. (2006), A Model of Forum Shopping, *American Economic Review* 96, 1091-1113.

Lerner, J. and Tirole, J. (2008), Public Policy Towards Patent Pools, in Jaffe, A., Lerner, J. and Stern, S. (eds), *Innovation Policy and the Economy* Vol. 8, pp. 157-186.

Love and Roper (1999) The Determinants of Innovation: R&D, Technology Transfer and Networking Effects, *Review of Industrial Organization* 15, 43–64.

Mangiarotti, G. and Riillo, C., 2014, Standards and Innovation in Manufacturing and Services: The Case of ISO 9000, *International Journal of Quality and Reliability Management* 31(4), 435-454.

Maskus, K.E., Otsuki, T. and Wilson, J.S. (2005), *The Cost of Compliance with Product Standards for Firms in Developing Countries: An Econometric Study*, World Bank Policy Research Working Paper 3590.

Merges, R. (1999), *Institutions for Intellectual Property Transactions: The Case of Patent Pools*, University of California at Berkeley, mimeo.

Michel, C. (2012), *Standardization of Infrastructure that Supports Innovation: The Case of the Dutch EV Charging Infrastructure,* Thesis.

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

Pohlmann, T. and Blind, K. (2012), *Cooperate to Declare. Firms' Cooperative Activities as Driving Forces of Patent Declaration on Technological Standards*, Working Paper.

Peters, B. and Rammer, C: (2013), Innovation Panel Surveys in Germany, in: Gault, F. (ed), *Handbook of Innovation Indicators and Measurement*, Edward Elgar, Cheltenham and Northampton, 135-177.

Rysman, M. and Simcoe, T. (2008), Patents and the Performance of Voluntary Standard-Setting Organizations, *Management Science* 54 (11), 1920-1934.

Scott, T.J. and Scott, J.T. (2015), Standards and Innovation: US Public / Private Partnerships to Support Technology-Based Economic Growth, *Economics of Innovation and New Technology* 24 (5), 457-489.

Shapiro, C. (2001), Navigating the Patent Ticket: Cross Licences, Patent Pools and Standard Setting, in: Jaffe, A., Lerner, J. and Stern, S. (eds), *Innovation Policy and the Economy*, vol. 1, MIT Press.

Shapiro, C. and Varian, H.R. (1998), *Information Rules – A Strategic Guide to the Networking Economy*, Havard Business School Press, Boston.

Shimbo, T., Nagaoka, S. and Tsukada, N. (2015), *Dynamic Effects of Patent Pools : Evidence from Inter-generational Competition in Optical Disk Industry*, RIETI Discussion Paper 15-E-132, Tokio.

Simcoe, T. (2007), *Explaining the Increase in Intellectual Property Disclosure*, Standards Edge: The Golden Mean, 260-295.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

Stephenson, S.M (1997), *Standards and Conformity Assessment as Nontariff Barriers to Trade*, World Bank Policy research Working Paper No. 1826.

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.

Swann, G.N.P. and Lambert, R. (2010), *Why Do Standards Enable and Constrain Innovation*, 15th EURAS Annual Standardization Conference, Lausanne.

Simcoe, T. (2012), Standard Setting Committees: Consensus Governance for Shared Technology Platforms, *American Economic Review* 102, 305.336.

Simcoe, T., Graham, S. and Feldman, M. (2009), Competing on Standards? Entrepreneurship, Intellectual Property and Platform Technologies, *Journal of Economics and Management Strategy* 18 (3), 775-816.

Standards Australia (2006), *Standards, Innovation and the Australian Economy*, Centre for International Eocnomics, Canberra.

Teece, D.J. and Sherry, E.F. (2003), Standards Setting and Antitrust, *Minnesota Law Review* 87, 1913-1994.

Vakili, K. (2015), *Collaborative Promotion of Fragmented Technology Standards and the Impact on Follow-on Innovation: Evidence from Modern Patent Pools*, Paper presented at Druid 2015, Rome.

Vaughan, F. (1956), *The United States Patent System: Legal and Economic Conflicts in American Patent History*, Norman, OK: University of Oklahoma Press.

Wakke, P., Blind, K. and Ramel, F. (2016), The Impact of Participation within Formal Standardization on Firm Performance, *Journal of Productivity Analysis*, DOI 10.1007/s11123-016-0465-3.

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5 Innovative Public Procurement (Commitment 17)

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5.1 Introduction

Commitment 17 of the EU's Innovation Union flagship initiative aims at creating markets for the public procurement of innovations across Europe. It consists of three milestones which were achieved by the end of 2015:

1. The European Commission provides guidance for public authorities and small and medium-sized enterprises on public procurement of innovation
2. A reform of public procurement directives and improvement of rules for joint procurement
3. The inclusion of public procurement related calls for proposals in Horizon 2020

Milestone 2 was probably the most significant step, which comprised adopting directives 2014/24/EU and 2014/25/EU replacing the older directives 2004/18/EC and 2004/17/EC on public procurement. The revised directives have been voted by the European Parliament and adopted by the European Council in 2014. Transposition into national law is required by April 2016 (http://ec.europa.eu/growth/single-market/public-procurement/new/index_en.htm).

The remainder of the paper is organized as follows: Section 5.2 portrays the policy makers rationale for the reforms initiated by Commitment 17 as to be found in official EU documents. Section 5.3 describes theoretical arguments for the link between public procurement and innovation made in the economic literature. Section 5.4 states the body of empirical evidence on the effectiveness of public procurement in fostering innovation.

5.2 Policy objectives tackled by Commitment 17

Implementation of commitment 17 aims at creating procurement markets for innovation across the EU comparable with those in the US (European Commission, 2015, 56.). The implementation of procurement markets in Europe should help to enhance the competiveness of European industry while improving public services and addressing social challenges at the same time (http://i3s.ec.europa.eu/commitment/21.html). Furthermore, the vision is to achieve a smart, sustainable and inclusive growth while ensuring an efficient use of public funds and also creating a framework to establish a sound commercial practice (Directive 2014/25/EU, 4).

Another rationale for the proposed reforms was to improve the quality of public services and the efficiency of public spending in the EU (European Commission 2015, 56; Directive 2014/24/EU, 2). The revision of EU directives related to public procurement made it easier for small and medium sized enterprises (SMEs) to participate in procurement calls (Directive 2014/24/EU, 2). Pre-Commercial Procurement (PPC) was put forward as a policy tool to "*enable public procurers to share*

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the risks and benefits of designing, prototyping, and testing new products and services with the suppliers" (https://ec.europa.eu/digital-agenda/en/pre-commercial-procurement). The European Commission explicitly acknowledged the fact that markets for public procurement were highly fragmented across the Union. Commitment 17 aimed at overcoming this fragmentation (European Commission 2011, iii; European Commission 2015, 56). Rules for the regulation of public procurement were harmonized. Further legal and administrative barriers that prevented the participation in cross-border tenders were removed. The scope of discriminatory purchasing was decreased by guaranteeing more transparency in the process (European Commission 2011, iv). The reform was tailored to provide a maximum of flexibility and transparency in the field of public procurement, as well as significant simplification and modernization (European Commission 2011, 9; Directive 2014/25/EU, 2) of the regulatory framework.

One of the most significant changes under directive 2014/25/EU is the possibility to include technical specifications and performance-related criteria in procurement tenders as long as they abide to the principles of transparency and open competition (paragraph 74). This is particularly relevant for the procurement of innovation because if the novel solutions envisioned by procurers are not explicitly specified in the selection rules it will be unlikely that firms offering innovative products are selected. Under the to be replaced directive 2004/18/EC selection of offers was based on a "lowest price" or "most economically advantageous" rule, i.e., "best value for money" (2004/18/EC, paragraph 46). Innovative solutions, however, require risky R&D activities. These additional costs are borne by firms and only passed on to consumers when a product or service is successfully commercialized. Consequently, although innovative solutions might be superior in terms of functionality and performance, as well as they comply with general policy goals such as sustainability and innovativeness, they are unlikely to be the cheapest or even the most economically efficient solutions if the criteria for defining efficiency do not include functional or performance specifications.

With commitment 17 public procurers in all member states were put in the position to pool their procurement efforts in joint calls (https://ec.europa.eu/digital-agenda/en/pre-commercial-procurement). Pooling procurement efforts contributes to reaching a critical mass of demand for innovative products which in turn facilitates to establish lead markets for innovations from public demand. Furthermore, the reform helped to accomplish optimum conditions for a wide commercialization and take-up of R&D efforts within individual member states (https://ec.europa.eu/digital-agenda/en/pre-commercial-procurement). In the sectors of water, energy, transport and postal service sectors policy makers acknowledged the closed nature of these markets, especially the fact, that entities operating in these fields had prior granted special or exclusive rights to a small number of market participants. Reform efforts under Commitment 17 ensured those markets to open up to competition of procurement (Directive 2014/25/ EU, 2).

Besides the aforementioned economic rationale behind the reform efforts of Commitment 17 policy makers also considered the social impact of the proposed reforms. The Innovation Union flagship initiative as a whole pursued the goal of addressing major societal challenges by developing innovative solutions for social changes and future challenges. Public procurement is able to support these societal goals by fostering demand for not yet established products and

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services with high social added value (European Commission 2015, 56; https://ec.europa.eu/digital-agenda/en/pre-commercial-procurement; Directive 2014/24/EU, 2).

5.3 Theoretical link between public procurement and innovation

The following sections discusses the theoretical link between public procurement and innovation and public procurement as a distinct policy tool for overcoming market failures associated with investments in innovation. Public procurement is thereby part of a broader policy mix (including, among others, intellectual property rights, direct subsidies for innovation activities, R&D tax credits and regulatory frameworks) that aims at promoting the capabilities of firms to develop innovative products and services (Guerzoni and Raiteri, 2014; Elder and Georghiou, 2007). Other than direct R&D subsidies or tax credits, however, it is a demand-side policy tool that operates by increasing demand for innovative solutions. Firms then respond with increased innovation efforts to develop new products and services and to provide better solutions than competing offers. Public entities issue calls for new technological solutions which might be (a) variations of already existing technologies tailored to the specific needs of the public, or (b) technologies which yet have to be developed to address a certain purpose of public relevance. In that way, public technology procurement can promote the development of new technologies (Aschoff and Sofka, 2009) and can also demonstrate demand for existing technologies to market participants (Guerzoni and Raiteri, 2014; Edquist and Zabala-Iturriagagoitia, 2012).

The literature usually distinguishes between different types of public procurement activities depending on the degree of innovative efforts that they stimulate. In the majority of cases, public procurement involve the purchase of already existing product demanded by the public sector which entails little to no innovation efforts by suppliers (Guerzoni and Raiteri, 2015; Edquist and Zabala-Iturriagagoitia, 2012).

Public procurement for innovation (PPI), however, occurs when a public agency orders a new product that does not yet exist but that can be developed in a conceivable period of time (Guerzoni and Raiteri, 2015; Edquist and Zabala-Iturriagagoitia, 2012). The development process by firms that win a tender involves respective R&D efforts, although this R&D could be of imitative nature. Furthermore, four types of PPI can further be distinguished. Direct public procurement of innovation occurs when the purchaser is also the end-user of the product, thereby the procuring public agency is using its own demand to influence innovation (Edquist and Zabala-Iturriagagoitia, 2012). Catalytic PPI means that the procuring organization acts as a catalyst and technical resource for the end-user and also coordinates everything on behalf of the end-user (Edquist and Zabala-Iturriagagoitia, 2012). Adaptive PPI means that the product or system ordered is new and innovative only to the country or region of the procurement; consequently, the innovation is only local (Edquist and Zabala-Iturriagagoitia, 2012). By contrast, developmental PPI occurs when a completely new product or system with no predecessor is created that is yet unknown worldwide. This form of PPI is highly creation oriented and the innovation can be regarded as a radical

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innovation (Edquist and Zabala-Iturriagagoitia, 2012).

Eventually, the literature mentions pre-commercial Procurement (PCP) which is characterized by the direct purchase of R&D and research results rather than buying products for specific applications. In that way, governments directly commission research projects by themselves (Edquist and Zabala-Iturriagagoitia, 2012). The aspired research results could either already exist, which resembles a form of licensing of new technologies by the inventors, in order to put the invention into the public domain (see also the concept of patent buyouts, Kremer, 1998). Or the research output may still be uncertain, which means that public entities incur the risk of unsuccessful research efforts. Successful results could then be marketed directly by the government or licensed out to interested customers.

Public procurement potentially leads to a double benefit for purchasers on the one hand, as they buy in new innovative solutions (e.g., innovative IT solutions for running the public administration more effectively), and suppliers on the other hand, as they benefit from customer feedback and a guaranteed levels of sales (Vecchiato and Roveda, 2014). Public entities can take the role of early adopters of new technologies when markets for these do not exist yet. This reduces the demand-side risk of developing new products and services. A first successful adoption of new technologies and the usage under real-life conditions then stimulates learning which possibly improves innovative products further and lowers costs of technology adoption (Edler and Georghiou, 2007). An initial level of public demand for a technology can thereby realize economies of scale which might be fundamental to a technology's commercial success (Edler and Georghiou, 2007). In addition, public adoption induces a "certification effect" which raises awareness and interest by private customers (Vecchiato and Roveda, 2014). This, in short, describes the concept of a "lead market" (Vecchiato and Roveda, 2014), which can be created with the help of public demand.

Stimulating demand for technical solutions that help to meet particular policy goals is one of the main reasons for the use of public procurement (Aschhoff and Sofka, 2009). The government can redirect funds to certain desirable technologies and thereby overcome market failures that arise, for example, in the adoption of green technologies (Acemoglu et al., 2012). In situation where markets are highly fragmented, public demand offers a focal point which can bring together private demand and supply for innovations and mobilize market participants and networks (Vecchiato and Roveda, 2014). In certain sectors, government actions even determine entirely the dynamics of an industry. Traditionally, innovative public procurement was concentrated in the realms of military or law enforcement in which demand stems exclusively from public sources. Public entities have thus nearly full control over the innovative efforts in these sectors, as well as the applied procurement practices directly influence the level and nature of competition in these industries.

Public procurement, as an innovation policy tool, demands a high level of involvement and efficiency by the procurers themselves to be effective. In an ideal situation the government has to predefine the functionality of the demanded product but, at the same time, neither define the technical specifications nor the specific design of the product (Aschhoff and Sofka, 2009). This is regarded as a specific advantage of the policy tool because the implementation of the innovation

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process is left to the creativity of private businesses. Hence, private suppliers are able to use the most effective and efficient technologies at their disposal to achieve the desired result (Aschhoff and Sofka, 2009). However, predefining the required functionality of products is by itself a non-trivial task. Procurers need to possess an adequate level of technical knowledge to be able to judge which type of R&D efforts are both feasible and promising. In case when public procurement is used to tackle societal challenges, these goals need to be formulated and weighed appropriately against other public interests which might stand in contrast to them (Edquist and Zabala-Iturriagagoitia, 2012). Public procurement, if misused, facilitates corruption and misappropriation of public funds (Edquist and Zabala-Iturriagagoitia). Nevertheless, as public procurement does not require assessment of individual technical solutions, but instead only the quality of the final product, it is likely less demanding than direct R&D subsidies.

Is there a specific group that can benefit specifically from public procurement compared to other innovation policy tools? As public authorities usually only contract with one company issuing the winning bid and tenders are announced infrequently, the system of public procurement is very competitive and selective (Guerzoni and Raiteri, 2015; Aschhoff and Sofka, 2009). Especially young and small companies are disadvantaged in the bidding process. The former often lack the specific networks with politicians and public servants as well as the market reputation that is necessary to be successful. The latter face tenders that might be too large for them to cope with as they lack the required capacity and resources (Aschhoff and Sofka, 2009). By contrast, young and small companies might be quicker in reacting to specific government requests, especially when the demanded solutions are very innovative and require thinking "out-of-the-box" of established product classes (Edler and Georghiou, 2007). The net effect of age and firm size on the propensity to participate successfully in innovative public procurement tenders is thus not clear and should be answered empirically.

Apart from that, regional market participants can benefit from innovative public procurement. This is because procurement usually addresses a local demand and local players have an advantage in terms of shorter distances to exchange information, personal contacts, cultural and social norms similar of those of the procurers, and mutual trust (Vecchiato and Roveda, 2014; Edler and Georghiou, 2007). Likewise, public authorities can also benefit from this tacit knowledge, as local players might offer solutions that are better tailored to their specific needs than firms outside of the specific regional context (Edler and Georghiou, 2007).

5.4 Empirical evidence on the effectiveness of public procurement as an innovation policy tool

Dalpé, DeBresson, and Xiaoping (1992) demonstrate the significance of public demand for innovation in the Canadian economy. They use a statistically representative survey of 1,845 innovations for the period of 1945 until 1978 and show that 25 % of these innovations are first adopted and used in the public sector. In the respective period, the Canadian government was an "*important client for the suppliers of new transport equipment (aircraft, rail, shipbuilding and other*

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vehicles), electrical and telephone equipment, new scientific instruments as well as new pharmaceutical products" (Dalpé et al., 1992, p. 255). The innovations adopted by the government also scored high on a constructed novelty index–higher than innovations first adopted by the private sector. The authors conclude that "*since we know that the first user plays an active role in the development of innovations [...], the weight of the public sector is important*" (p. 260).

Further, 13 % of Canadian patents have a potential use in the public sector; a result which is derived from statistics provided by the Canadian Patent Office. 8% of the production in Canadian manufacturing in 1979 is acquired by the public sector. Public demand is thereby concentrated in a relatively small number of industries. A more detailed analysis shows that "*the public sector is an important buyer for a number of innovative supplier industries, which in turn supply many other industries*" (p. 261). Because of the influence of initial demand on product development and design, the government thus exerts an indirect influence on innovation activities in other sectors.

Aschhof and Sofka (2009) study a sample of 1,100 German companies in the period of 2000 until 2002. In a multivariate regression analysis they find that public technology procurement has a significantly positive effect on firms' share of turnover with products that are new to the markets. Consequently, the authors consider the output additionality of procurement contracts rather than whether they increase firms' input to the innovation process (i.e., innovation expenditures). The promotion of market novelties is thereby not limited to traditional sectors such as the military or the police but applies to a broad fraction of the economy. However, positive response by firms to public procurement is heterogeneous and strongest for smaller firms in less economically dynamic regions of Germany. The authors therefore suspect that "*public procurement may be especially promising for firms with limited resources*" (Aschhof and Sofka, 2009, p. 1234). Eventually, the effectiveness of public procurement is compared to other policy tools such as regulations, R&D subsidies and the funding of basic research at universities. Knowledge spillovers from domestic universities have a comparably large effect on sales with market novelties as public procurement. By contrast, regulations as an impulse for innovation and direct R&D grants to firms show no positive effect in the sample under study. A caveat to these favorable results concerning the effectiveness of public procurement is the fact that public procurement was the least important of all considered policy tools with only 5 % of firms that were involved in procurement contracts.

Guerzoni and Raiteri (2015) provide empirical evidence on the effectiveness of public procurement using a survey of 5,238 senior company managers in 27 member states of the EU. They find that winning a procurement contract that includes the possibility to sell an innovation in the period of 2006 until 2008 significantly increases the likelihood for the surveyed managers to report positive changes in innovation expenditures in 2008 compared to the level of 2006. Although their dependent variable is categorical and thus only allows for a qualitative assessment of the change in innovation expenditures, Guerzoni and Raiteri are able to make statements about the input additionality of public procurement. This might be an advantage, depending on the question of interest, to the study of Aschhof and Sofka (2009) because many of the theoretical arguments concerning the relationship between public procurement and innovation imply an effect on private investments in innovation rather than the successful commercialization of innovations. Moreover, Guerzoni and Raiteri study the effect of public procurement in relation to other innovation policies,

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namely R&D grants and tax credits. Although, also for these policies, the study suffers from rather vague qualitative measures for the variables of interest23, because the estimated average treatment effect on the treated (ATT) for public procurement is larger than for R&D grants and tax credits, the authors conclude that procurement might be the most effective of the considered policies. However, an assessment of the statistical significance of these differences in ATTs is not conducted. Eventually, the analysis identifies a possible interaction effect of demand and supply-side policies as the effect of public procurement is lower when studied in isolation, i.e., when R&D grants and tax credits are absent, compared to the effect when R&D grants and tax credits are kept at their (in the population) naturally occurring level.

5.5 References

Acemoglu, D., P. Aghion, L. Bursztyn, and D. Hemous (2012): The Environment and Directed Technical Change. *The American Economic Review*, 102(1): 131–166.

Aschhoff, B., and W. Sofka (2009): Innovation on demand – Can public procurement drive market success of innovations? *Research Policy* 38, 1235 – 1247.

Dalpé, R., C. DeBresson, and H. Xiaoping (1992): The public sector as first user of innovations. *Research Policy* 21, 251 – 263.

Edler, J., and L. Georghiou (2007): Public Procurement and innovation – Resurrecting the demand side. *Research Policy* 36, 949 – 963.

Edquist, C., and J. M. Zabala-Iturriagagoitia (2012): Public Procurement for Innovation as mission-oriented innovation policy. *Research Policy* 41, 1757 – 1769.

European Commission (2011): *Evaluation Report: Impact and Effectiveness of EU Public Procurement Legislation – Part 1*. Brussels, Commission Staff Working paper.

European Commission (2015): *State of the Innovation Union*. Luxembourg, Publications Office of the European Union.

Guerzoni, M., and E. Raiteri (2015): Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix. *Research Policy* 44, 726 – 747.

Kremer, M. (1998): Patent Buyouts: A Mechanism for Encouraging Innovation. The *Quarterly Journal of Economics* 113 (4), 1137-1167.

Vecchiato, R., and C. Roveda (2014): Foresight for public procurement and regional innovation policy: The case of Lombardy. *Research Policy* 43, 438 – 450.

[23] R&D grants are measured as a dummy "which takes the value 1 if a firm reported that 'changes in public financial support' had a positive effect on innovation". In the same spirit, tax credits are measured as a dummy „with a value 1 for firms reporting that 'changes in tax environment (e.g. R&D or innovation tax credits)' had a positive effect on innovation" (Guerzoni and Raiteri, 2015, p. 732.

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6 Bottlenecks, Challenges and Opportunities for Eco-Innovation (Commitment 18)

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6.1 Introduction

Given the benefits they can generate, innovation, and with it environmental innovation, has been moved into the center of the Europe 2020 strategy for smart, sustainable and inclusive growth and job creation. According to the European Commission (2011) '*Eco-Innovation is any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources*'.

Particularly, eco-innovation has the potential to produce dual advantages: on the one hand, eco-innovation can address the EU's current key societal challenges by tackling climate change, helping to improve environmental protection and resource efficiency of the economy or to guarantee secure, clean and efficient energy. On the other hand, eco-innovations can contribute strongly to the EU's competitiveness and growth, mitigating the persistent aftereffects and ills of the Global Financial Crisis that still weigh on and stifle the EU. Hence, to fully embrace and harness its full potential, the uptake of eco-innovation needs to be fostered and facilitated and still existing barriers need to be dismantled to promote, accelerate and diffuse eco-innovation in society.

In this context, in what follows, an overview and discussion of the literature on the importance of different drivers and barriers and the economic effects of eco-innovations is provided. That way, vital barriers and drivers can be identified, pointing to key bottlenecks and deficiencies as well as areas of policy intervention.

6.2 Drivers and barriers of eco-innovations

Because of the important role attributed to eco-innovations together with the proliferation of and easier access to relevant data sources, identifying key driving forces behind eco-innovations has received a fair amount of attention recently. Generally, the environmental economics and innovation literature distinguishes between three different types of drivers: (i) demand pull factors, (ii) technology push factors, and (iii) regulations, which will be discussed separately in what follows.

6.2.1 Demand pull factors

Empirically, a number of different demand-related factors and indicators have been used to shed

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light on their role for eco-innovations. In spite of the diversity of indicators used and countries covered, empirical evidence rather consistently highlights that demand is an essential driver of eco-innovations.

For instance, Horbach (2008) points to the importance of expectations regarding the development of the business cycle and demonstrates for a set of German manufacturing firms that strong **(expected) demand** in the future triggers present environmental innovations. The dominant role of demand expectations is also highlighted by the Flash Eurobarometer (2011) for which some 5,000 managers of SMEs in 27 EU Member States in selected sectors were interviewed in 2011. Accordingly, almost 70 percent of the managers considered uncertain demand from the market as very serious or somewhat serious problem for the development and uptake of eco-innovations.

Moreover, **customer benefits** of eco-products like cost or energy savings, improved product quality and durability or reduced health impacts encourage eco-innovations by creating or increasing demand which in turn induces firms to invest in and introduce eco-innovations (Kammerer, 2009). In a similar vein, firms that believe that customers expect environmentally friendly products are also more likely to eco-innovate (Doran and Ryan, 2012).

Strong **environmental consciousness of customers** matters strongly for a firm's decision to eco-innovate. In this respect, Triguero et al. (2015) show that increasing demand for green products is an important driver of eco-innovations among European SMEs. In a similar vein, the management literature attributes a non-negligible role to corporate social responsibility (CSR), emphasizing that societal pressure and strong demand for environmentally-friendly products and processes induces firms to eco-innovate. Kesidou and Demirel (2012) in their study on a sample of UK firms highlight that CSR plays an important but somewhat differentiated role: while it is an important determinant of a firm's decision to invest in eco-R&D, it however matters little for the level of eco-R&D.

The positive effect of a strong **cost-saving motive** is confirmed empirically, rendering firms that intend to save material or energy costs not only more likely to eco-innovate (Horbach, 2008; Horbach et al., 2012; Kesidou and Demirel, 2012) but also more willing to invest more in eco-innovative activities (Kesidou and Demirel, 2012).

On the contrary, empirical evidence is mixed and country-specific concerning the role of **international market** outreach for eco-innovations but seems to suggest that due to fiercer competitive pressures and the need to diversify, exposure to and presence in international markets is conducive to eco-innovations. For instance, Horbach (2008) finds that German manufacturing firms that predominantly sold in international markets were also more likely to eco-innovate. Similarly, Ghisetti et al. (2015) demonstrate for a large sample of European firms that exporters are more likely to eco-innovate while, on the contrary, De Marchi (2012) emphasizes that exporting Spanish firms are less likely to eco-innovate.

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6.2.2 Technology push factors

Likewise, a variety of different technology push factors have been identified as important drivers of eco-innovations. Empirically, a firm's **technological capabilities** – i.e. the particular resources needed to adopt, adapt, generate and manage technical change, including R&D investments, skills, knowledge and experience – are a key force behind eco-innovations. Specifically, eco-innovations are more likely among firms that invest in R&D (Horbach, 2008; Horbach et al, 2012; Ghisetti et al., 2015;), that invest in R&D on a continuous basis (De Marchi, 2012) and whose workforce is highly qualified (Horbach, 2008; Borghesi et al., 2011). Furthermore, R&D investments are also important for a firm's decision to enlarge its eco-innovation portfolio and expand its number of eco-innovation typologies (Ghisetti et al., 2015). Moreover, given the high degree of novelty of eco-innovations that require sizeable R&D investments, complementary investments in machinery and equipment and software are necessary for successful eco-innovative activities (De Marchi, 2012; Horbach et al., 2012).

In addition to technological capabilities, the buildup of **organizational capabilities** and practices triggers eco-innovations. In this respect, Environmental Management Systems (EMS) – i.e. a set of processes and practices that help firms to reduce their environmental impacts and increase their efficiency – which are instrumental for the development of organizational environmental capabilities, are found to spur eco-innovations, in particular process eco-innovations, among firms (Horbach et al., 2012; Kesidou and Demirel, 2012). Furthermore, general organizational innovations, like new forms of labor organization or new methods of organizing business processes, are conducive to eco-innovations (Horbach et al., 2012).

Furthermore, **information** is a key ingredient for innovations, particularly eco-innovations, which is a young and very dynamic technological area and whose success therefore hinges on high-quality internal and external information, stemming from, e.g., customers, suppliers, competitors, consultants, universities or research institutes but also from conferences and exhibitions, scientific journals or associations. Empirically, good access to external information and knowledge is found to spur eco-innovations, particularly eco-product and eco-organizational innovations (Triguero et al., 2013). However, the effect of external information on a firm's eco-innovativeness differs by particular source of information and varies strongly across types of eco-innovations and countries, highlighting the importance of national systems of innovations for eco-innovative outcomes (see, e.g., Horbach et al., 2012 for Germany, Horbach et al., 2013 for a comparison between Germany and France, or Borghesi et al., 2011 for Italy).

In a similar vein, **cooperative activities** of firms are of non-negligible importance for their eco-innovativeness. Generally, such cooperations are helpful to either compensate for prevailing deficiencies in internal resources and competencies, to reduce and share the risks and/or costs associated with eco-innovations, but also to get better access to markets or to realize economies of scale and scope in eco-R&D activities. For instance, empirical evidence stresses that past R&D cooperations are more important for eco-innovations than non-eco-innovations (Horbach et al.,

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2012) or that cooperations encourage the adoption of eco-innovations (Ghisetti et al., 2015) but that the choice of particular cooperation partner is pivotal to the outcome of the cooperative arrangement. In this respect, given the novelty and uncertainty surrounding the field of eco-innovations, collaborations with universities, research institutes and R&D labs are of particular importance for eco-innovation success (De Marchi, 2012; Ghisetti et al., 2015; Triguero et al., 2013;)

In contrast to Schumpeter's (1934) **competition**-curbs-innovation hypothesis which highlights that competition lowers the expected return from R&D and therefore tends to lower R&D efforts of firms, competition – in terms of a high risk of market entry of new competitors – is found to trigger eco-innovative efforts of firms (Horbach et al., 2012). A similar positive effect on eco-innovations is found for prevailing **appropriability conditions**, which help reduce the extent of knowledge spillovers and therefore induce firms to more strongly engage in eco-innovative activities (Horbach et al., 2013).

6.2.3 Public policy: regulations and subsidies

Theoretically, given the peculiarities of eco-innovations in terms of cost-saving and earnings potentials, on the one hand, and an associated dual externality issue, on the other, there is generally a strong need for regulations to stimulate eco-innovative activities among firms.

In particular, as has been highlighted by Porter and van der Linde (1995:98) '...properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them'. Accordingly, due to their lacking experience with environmental matters, entrepreneurs are unable to recognize the cost-saving potential of environmental innovations and therefore fail to realize environmentally and economically beneficial innovations. Hence, environmental regulations are strongly needed which, in turn, help create win-win situations: regulations induce entrepreneurs to invest in environmental R&D to comply with environmental regulation standards and, at the same time, enable them to reduce their production costs, increase their profits and competitiveness or enter markets for eco-products. Furthermore, the need for regulation is also emphasized by the so-called 'double externality problem' inherently connected to eco-innovations. Particularly, eco-innovations produce two types of positive externalities, (i) knowledge externalities, on the one hand, and (ii) externalities due to the positive impact on the environment, on the other. Hence, in the face of this double market failure, characterized by private returns to R&D falling short of their social returns, firms tend to underinvest in R&D, justifying or necessitating even the use of policy instruments like regulations to realize the socially desirable level of investment in eco-innovations.

Empirically, there is strong evidence underscoring the importance of **regulations** for eco-innovative activities. In particular, in line with and support of the Porter-hypothesis, more stringent regulations are found to strongly encourage firms to eco-innovate (Doran and Ryan, 2012; Horbach, 2008; Horbach et al., 2012; Horbach et al., 2013; Kammerer, 2007). However, as suggested

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by Horbach et al. (2012), the effect of regulations tends to differ by type of environmental impact and innovation. Specifically, present and future regulations are relevant for almost all process-related eco-innovations. However, while present regulations are of little importance for product-related eco-innovations, future (expected) regulations help trigger all product-related eco-innovations. Furthermore, empirical evidence also points to likely differences across firm-size. As highlighted by Triguero et al. (2013) for a large set of European SMEs, existing regulations help trigger both product and organizational eco-innovations but fail to encourage product eco-innovations of SMEs. On the contrary, future regulations were unable to trigger any eco-innovations at all. In this regard, interesting empirical evidence as to the effectiveness of the European Emission Trading System (EU ETS) is provided by Borghesi et al. (2011) for Italy who highlight that while, in general, the EU ETS played a limited role only, it nonetheless helped trigger particular eco-innovations (like energy efficiency innovations or innovations that help reduce atmospheric and water emissions).

However, while a generally positive regulation-push effect is observable for a firm's decision to eco-innovate, still very little is known about the role of (stringent) regulations for the intensity of eco-innovations. One notable exception is the study by Kesidou and Demirel (2012) for a set of UK manufacturing firms who show that while the stringency of environmental regulations does not matter for a firm's probability to eco-innovate, it however, strongly matters for the amount of resources allocated to eco-innovative activities, inducing entrepreneurs to spend more on environmental innovations. This suggests that regulations are also an important determinant of the resources spent on eco-innovative activities. But this positive regulation-push effect only holds for firms with very little and very high investments in eco-innovations, successfully encouraging them to invest more.

In addition to regulations, public policies in general and environmental policies in particular matter for eco-innovations: accordingly, easy access to **subsidies** and fiscal incentives are expected to facilitate and encourage eco-innovations. This assertion finds support from the Flash Eurobarometer (2011) which highlights that among a set of European SMEs, the majority of managers (60%) considered insufficient access to existing subsidies and fiscal incentives a very serious or somewhat serious barrier to an accelerated development and uptake of eco-innovation. In general, however, no consistent positive effect if subsidies is observable empirically. While general public support produces mixed results, failing to generate the desired positive effect at times (Horbach et al., 2013; Triguero et al., 2013), environmental public support for eco-innovation helps to trigger eco-innovations (Ghisetti et al., 2015). This positive environmental policy effect however differs by type of technology impact and appears most relevant for the reduction of CO2 and other air emissions in firms, on the one hand, and the reduction of energy use and air, water, soil and noise pollution during after-sale-consumption, on the other (Horbach et al., 2012).

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6.2.4 Firm specific factors

In addition, previous studies on environmental innovation highlight that eco-innovations are also driven and determined by several structural firm-specific characteristics. In particular, **firm size** matters: in support of Schumpeter's (1942) positive firm size-innovation hypothesis which emphasizes the difficulty of smaller firms in raising external capital due to capital market imperfections, larger firms are found to be consistently more likely to eco-innovate (Horbach, 2008; Horbach et al., 2012, Horbach et al., 2013; De Marchi, 2012, Kesidou and Demirel, 2012; Triguero et al., 2013).

On the contrary, **firm age** seems to play no significant role for eco-innovations (Horbach, 2008; Horbach et al., 2012), neither supporting Arrow's (1962) positive age-innovation hypothesis which stresses that as a result of learning-by-doing, older firms tend to be more knowledgeable, efficient and innovative, nor Agarwal and Gort's (1996 and 2002) negative age-innovation hypothesis which emphasizes the role of organizational rigidities, rendering firms inflexible and rigid and unresponsive to frequently changing market conditions as they grow older.

Furthermore, **affiliation** to either a domestic or a foreign parent company produces mixed empirical results. For instance, Ghisetti et al., (2015) show that affiliation to a multi-national corporation is advantageous, encouraging subsidiaries to adopt eco-innovations as well as to expand their portfolio of different types of eco-innovations. In contrast, De Marchi (2012) fails to find any significant effect of a subsidiary's affiliation to either a domestic or foreign parent company on eco-innovative activities, which may be due to the parent company's preference to centralize and concentrate eco-innovative activities at the parent company..

6.3 Effects of eco-innovations

From a policy-point of view, the particular economic and environmental effects of (technical and non-technical) eco-innovations are pivotal and form the key rationale for devising and implementing appropriate policies. Empirically, numerous studies have looked at the effects of eco-innovations on both firms' economic as well as environmental[24] performance, utilizing various different performance indicators. By and large, eco-innovations are found to exert a positive effect on firm performance.

For instance, with respect to **labor productivity**, Marin (2012) and Marin and Lotti (2014) use extended CDM models (Crépon et al., 1998) to shed light on drivers and effects of eco-innovations and demonstrate that eco-innovations - proxied by environmental patents – exert a strong positive effect on labor productivity of Italian manufacturing firms. However, at least in the short run, environmental innovations are found to crowd out other, more profitable, non-environmental

[24] See, e.g., Cheng et al. (2014), Dong et al. (2014) or Lee and Min (2015) for studies on environmental effects of eco-innovations.

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innovations. A similar approach taken by Doran and Ryan (2012) shows that eco-innovations are an important driver of labor productivity growth of Irish firms: firms that engage in eco-innovations are characterized by higher labor productivity levels than those that introduce non-eco-innovations as well as firms that do not engage in eco-innovations at all.

Just like regular innovations, eco-innovations also have a **growth**-enhancing effect. For instance, Colombelli et al. (2015) study a set of European firms and suggest that firms that produce green technologies and apply for green patents also grow faster than those which produce regular innovations. Moreover, a comparison between high-growth firms – so-called gazelles – and non-high-growth firms shows that this growth-enhancing effect of green technologies is particularly strong among gazelles but absent among non-high-growth firms.

A similarly advantageous effect of eco-innovations is observable for firm **profits**. In this respect, Rexhäuser and Rammer (2013) use the German CIS to shed light on the effects of regulation-induced innovations relative to voluntary innovations. They show that profitability-effects differ by type of innovation and technology. Specifically, relative to firms that did not introduce environmental innovations, firms that introduce both, regulation-induced as well as voluntary innovations that improve resource efficiency (i.e. energy and material input) observe a profitability-enhancing effect. On the contrary, however, a negative profitability-effect is observable for firms that introduce regulation-induced innovations that reduce environmental externalities only (without also increasing resource efficiency). Likewise, Lanoie et al. (2011) use firm-level data for a set of OECD countries and demonstrate that environmental R&D has a positive effect on profitability.

Finally, the **employment**-effects of innovation, in general, and of eco-innovations, in particular, have received a great deal of attention. Theoretically, eco-innovations may both, create and destroy jobs, rendering the net-effect an a-priori unclear outcome. In general, whether eco-innovations create or destroy jobs depends on the type of innovation considered. By and large, while product eco-innovations have an employment-enhancing effect, the effects of process eco-innovations are mixed and inconclusive. For instance, Horbach (2010) shows that German firms belonging to the environmental sector that improved or developed new products expanded their employment levels. Likewise, Licht and Peters (2013 and 2014) shed light on the differentiated effect of different types of eco-innovations on employment. They highlight that both environmental and non-environmental product innovations have a positive employment effect in general, whereas the effect of both types of process innovations is either negative or of very little importance. Furthermore, no uniform pattern emerges as to the relative employment-effects of environmental and non-environmental product innovations, stressing the importance of country-specific factors and policies for employment outcomes. A similarly mixed picture is drawn by Rennings and Zwick (2002) who show that both product and services eco-innovations create more jobs than process eco-innovations while Harabi (2000) finds a long-term positive employment effect of product innovations among European firms but no significant effect of process or organizational innovations. Likewise, Kunapatarawong and Martinez-Ros (2014) show that eco-

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innovators grow faster, irrespective of whether environmental innovations are introduced voluntary or in response to regulations.

6.4 Summary and conclusion

Environmental innovations have the potential to bring two highly desirable benefits about: tackle climate change and improve environmental protection and resource efficiency, on the one hand, and contribute to competitiveness and growth, on the other. To that end, the uptake of eco-innovations in society needs to be fostered and facilitated, calling for the dismantling of non-negligible barriers and the identification and support of key drivers.

The above discussion points to important drivers of eco-innovations, differentiating between (i) demand pull factors, (ii) technology push factors, and (iii) regulations. It highlights that demand is an essential driver of eco-innovations and shows that expected future demand, customer benefit, customer's environmental consciousness, firms' strong cost-saving motive with respect to material and energy costs as well as their international trading activities are all important drivers behind eco-innovations. Furthermore, particular technology push factors like a firm's technological and organizational capabilities in terms of internal R&D and human capital endowment or EMS, the source of external information, cooperative activities – particularly with universities, research institutes and R&D labs – or competitive forces strongly affect the eco-innovativeness of firms. In addition, in support of the so-called Porter hypothesis (Porter and van der Linde, 1995), regulations are found to be a key driving force behind eco-innovations. A similar positive role is attributed to environmental subsidies.

Environmental and economic effects of eco-innovations are of great environmental, economic and political importance, justifying the emphasis on eco-innovations to tackle climate change and help increase resource-efficiency or guarantee secure, clean and efficient energy, on the one hand, and to also improve firms' economic performance, on the other. By and large, numerous studies point to the positive effects on both, a firm's environmental as well as economic performance, in terms of higher labor productivity, profits, firm sales and employment growth.

Hence, from a policy-point of view, the pivotal role of regulations and environmental subsidies places great emphasis on the role of public policies in fostering eco-innovations, particularly since eco-innovations are found to generate positive environmental and economic effects.

6.5 Data Collection

For this commitment data has been collected from the Government Budget Appropriations or Outlays on R&D (GBOARD).

The study on "Geography of expenditure" is one of the Work Packages of the ex post evaluation of Cohesion Policy programmes 2007-2013, which focuses on the European

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Regional Development Fund (ERDF) and the Cohesion Fund (CF). Its purpose was to collect data on the cumulative allocations to selected projects and the expenditures of both ERDF and CF programmes at the NUTS3 level of EU regions for all 28 EU countries and covered the Convergence, Regional Competitiveness and Employment (RCE) as well as the European Territorial Cooperation (ETC) Objectives for the period 2007-2013. As part of the study, the 2007-2013 dataset was consolidated with similar data for the period 2000-2006, to create a unified database for the last two programming periods at NUTS2 level.

Furthermore, the Eco-Innovation Scoreboard is the first tool to comprehensively assess and compare eco-innovation performance across the EU-27 and EU-28 Member States. The Eco-Innovation Scoreboard is an index based on indicators in five areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency outcomes and socio-economic outcomes.

Finally, Community Innovation Survey data was collected. Data capture the share of establishments that introduced a product and/or process environmental innovation; it comes from the following question 'During the three years 2006 to 208, did your enterprise introduce a product (good or service), process, organisational or marketing innovation with any of the following envionmental benefits?'.

6.6 References

Agarwal, R. and M. Gort, 2002, Firm product life cycles and firm survival, American Economic Review, 92, 184-90.

Arrow, K.J., 1962, The economic implications of learning by doing, American Economic Review, 29, 155-73.

Borghesi, S., G. Cainelli and M. Mazzanti, 2011, Brown sunsets and green dawns in the industrial sector: Eco innovations, firm behavior and the European Emission Trading, Società italiana di economia pubblica.

Cheng, C.C.J., C-L Yang and C. Sheu, The link between eco-innovation and business performance: a Taiwanese industry context, Journal of Cleaner Production, 64, 81-90.

Colombelli, A., J. Krafft and F. Quatraro, 2015, Eco-innovation and firm growth: Do green gazelles run faster? Microeconometric evidence from a sample of European firms, WWW for Europe Working Paper No. 88.

Crépon, B., E. Duguet and J. Mairesse, 1998, Research, Innovation, and Productivity: An Econometric Analysis at the Firm Level, NBER Working Paper Series No. 6696.

De Marchi, V., 2012, Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms.

Dong, Y., X. Wang, J. Jin, Y. Qiao and L. Shi, 2014, Research on effects of eco-innovation types and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

regulations on firms' ecological performance: Empirical evidence from China, Journal of Engineering and Technology Management, 34, 78-98.

Doran, J. and G. Ryan, 2012, Regulation and Firm Perception, Eco-Innovation and Firm Performance, MPRA Paper No. 44578.

European Commission, 2011, Innovation for a sustainable Future - The Eco-innovation Action Plan (Eco-AP), Brussels.

Flash Eurobarometer, 2011, Attitudes of European entrepreneurs towards eco-innovation, Analytical report, Flash EB Series #315.

Ghisetti, C., A. Marzucchi and S. Montresor, 2015, The open eco-innovation mode. An empirical investigation of eleven European countries, Research Policy, 44, 1080-1093.

Harabi, 2000, Employment Effects of Ecological Innovations: An Empirical Analysis, MPRA Paper No. 4395.

Horbach, J., 2010, The Impact of Innovation Activities on Employment in the Environmental Sector – Empirical Results for Germany at the Firm Level, Jahrbücher f. Nationalökonomie u. Statistik, Vol. 230(4).

Horbach, J., 2008, Determinants of environmental innovation – New evidence from German panel data sources, Research Policy, 37, 163-173.

Horbach, J., V. Oltra and J. Belin, 2013, Determinants and Specificities of Eco-Innovations Compared to Other Innovations – An Econometric Analysis for the French and German Industry Based on the Community Innovation Survey, Industry and Innovation, 20(6), 523-543.

Horbach, J., Ch. Rammer and K. Rennings, 2012, Determinants of eco-innovations by type of environmental impact – The role of regulatory push/pull, technology push and market pull, Ecological Economics, 78, 112-122.

Kammerer, D., 2009, The effects of customer benefit and regulation on environmental product innovation. Empirical evidence from appliance manufacturers in Germany, Ecological Economics, 68, 2285-2295.

Kesidou, E. and P. Demirel, 2012, On the drivers of eco-innovations: Empirical evidence from the UK, Research Policy, 41, 862-870.

Kunapatarawong, R. and E. Martinez-Ros, 2014; Environmental innovation and its impact on employment, Universidad Carlos III de Madrid.

Lanoie, P., J. Laurent-Lucchetti and N. Johnstone, 2011, Environmental Policy, Innovation and Performance: New Insights on the Porter Hypothesis, Journal of Economics & Management Strategy, 20(3), 803-841.

Lee, K-H and B. Min, 2014, Green R&D for eco-innovation and its impact on carbon emissions and firm performance, Journal of Cleaner Production, 167, 1-11.

Licht, G. and B. Peters, 2014, Do Green Innovations stimulate Employment? – Firm-level Evidence from Germany, WWW for Europe Working Paper No. 53.

Licht. G. and B. Peters, 2013, The Impact of Green Innovation on Employment Growth in Europe, WWW for Europe Working Paper No. 50.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645884.

Marin, G., 2012, Do Eco-Innovations Harm Productivity Growth through Crowding Out? Results from an Extended CDM Model for Italy, IMT Lucca EIC Working Paper Series No. 03-2012.

Marin, G. and F. Lotti, 2014, Drivers and Effects of Eco-innovations Using Data on Eco-patents, CERIS-CNR and Bank of Italy.

Mazzanti, M. and R. Zoboli, 2006, Examining the Factors Influencing Environmental Innovations, Fondazione Eni Enrico Mattei Working Paper No. 20.2006.

Porter, M.E. and C. van der Linde, 1995, Toward a new conception of the environment-competitiveness relationship, Journal of Economic Perspectives, 9(4), 97-118.

Rennings, K. and T. Zwick, 2002, Employment Impact of Cleaner Production on the Firm Level: Empirical Evidence from a Survey in Five European Countries, International Journal of Innovation Management, 6(3), 319-342.

Rexhäuser, S. and Ch. Rammer, 2011, Unmasking the Porter Hypothesis Environmental Innovations and Firm-Profitability, ZEW Discussion Paper No. 11-036.

Schumpeter, J. A., 1934, *The Theory of Economic Development*, Cambridge: Harvard University Press.

Schumpeter, J.A., 1942, *Capitalism, Socialism and Democracy*, New York: Harper.

Triguero, A., L. Moreno-Mondéjar and M.A. Davia, 2013, Drivers of different types of eco-innovation in European SMEs, Ecological Economics, 92, 25-33.

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