Innovation and diffusion of clean/green technology: Can patent commons help? ☆

Bronwyn H. Hall [a,b,c,d], Christian Helmers [e,*]

[a] University of Maastricht, The Netherlands
[b] UC Berkeley, NBER, USA
[c] UNU-MERIT, The Netherlands
[d] IFS, UK
[e] Universidad Carlos III de Madrid, Spain

ARTICLE INFO

ABSTRACT

This paper explores the characteristics of 238 patents on 90 inventions contributed by major multinational innovators to the "Eco-Patent Commons", which provides royalty-free access to third parties to patented innovations on green technologies. We compare the pledged patents to other patents in the same technologies or held by the same multinationals to investigate the motives of the contributing firms as well as the potential for such commons to encourage innovation and diffusion of climate change related technologies. We find pledged patents to protect environmentally friendly technologies and to be of similar value as the average patent in a pledging firm's patent portfolio but of lower value than other patents in their class. Our analysis of the impact of the patent commons on diffusion of patented technologies suggests that making patents accessible royalty-free did not result in any significant increase in diffusion as measured by citing patents. This study, therefore, indirectly provides evidence on the role of patents in the development and diffusion of green technologies.

© 2013 Elsevier Inc. All rights reserved.

1. Introduction

Numerous well-known economists have called for policies to encourage both public and private investment in technologies designed to mitigate climate change [27,7,20,3]. Policy in this area confronts a double externality problem [28]: the first is private underinvestment in R&D due to partial lack of appropriability and imperfections in the financial markets and the second is the fact that climate change mitigation and reduction in greenhouse gases is a classical public good, and one with a substantial international component. That is, the benefits of climate change mitigation flow largely to those who do not bear the costs. Hall and Helmers [10] argue that the existence of the second externality can impact the

desirability of policies designed to deal with the first externality, shifting policy makers' preferences towards subsidies or prizes and away from intellectual property (IP) protection.[1]

To make this argument more explicit, consider the usual policies designed to close the gap between the private and social returns to an activity.[2] These are subsidizing (or issuing tax credits for) the activity, regulating the activity (mandating its performance or controlling the price of inputs), and internalizing the externality by granting property rights that allow some appropriation of the social benefits. In the case of R&D investment, the first approach has been widely used in the past for research directed towards national needs [26], for corporate R&D via tax credits, and for small and medium-sized enterprises (SMEs) that face credit constraints. Examples of the second approach are the mandate of the State of California for sales of electric-powered automobiles [19] and the U.S. federal government stimulus package, which mandates the diffusion of electronic medical records and their effective use [4].

The most widely available policy designed to encourage private R&D investment in most countries is the intellectual property system. However, in the case of climate change mitigation and environmental protection more generally (as in the case of R&D directed toward other national needs such as public health), allowing firms to appropriate social benefits via their market power and pricing behavior has the drawback that without further policy design, it will tend to inhibit the diffusion of the technologies whose creation it encourages. In addition to the welfare cost of limited diffusion, IP protection also has potential negative consequences for subsequent innovation that builds on the protected technologies. Given the environmental externality, such diffusion and follow-on innovation is highly desirable. This has triggered an active debate on the role and usefulness of IPRs in the generation of climate change related innovation and its diffusion.[3] The existing evidence suggests that the IP system, specifically the patent system, may not be the optimal policy to encourage R&D in this area.

A number of large multinational firms such as Sony, IBM, Nokia, etc., claim to address the problems that patents might cause in the area of environmental protection through the creation of an "Eco-Patent Commons" (henceforth *EcoPC*) together with the World Business Council for Sustainable Development (http://www.wbcsd.org). Firms pledging patents to this commons are required to sign a non-assertion pledge that allows third parties royalty-free access to the protected technologies. The official purpose of this private initiative is described on the EcoPC website as the following:

- To provide an avenue by which innovations and solutions may be easily shared to accelerate and facilitate implementation to protect the environment and perhaps lead to further innovation.
- To promote and encourage cooperation and collaboration between businesses that pledge patents and potential users to foster further joint innovations and the advancement and development of solutions that benefit the environment.

Obviously, one can imagine an additional purpose: to improve the reputation and public relations of the participating firms, possibly by contributing patents on inventions of little value and the donation, therefore, generating little cost to the firm. However, it is worth noting that several of these firms have a number of other initiatives in the environment and sustainability areas, so this initiative probably forms part of a larger program whose cost is not negligible.[4]

Alternatively, the patents contributed could be those on inventions that need development effort that the firms in question are not willing to undertake.[5] To date, there are 12 participating firms, and 121 patents have been contributed to the commons.[6] Relative to the size of these firms' patent portfolios, this is a small number; however, it could be large given the small share of patents directly related to environmental protection in these firms' total patenting.[7]

The question that we ask is whether the EcoPC initiative achieves its ambitious official objectives. In order to provide an answer to this broad question, we answer a range of intermediate questions: (a) how and to what extent are the patented technologies related to environmental protection? (b) Are the patents that protect these technologies valuable? (c) Will royalty-free access to the EcoPC patents lead to more diffusion of the protected technologies and the generation of sequential

---

[1] The double externality is not specific to R&D directed toward environmental protection, but for example also affects R&D in the area of public health.

[2] We note in passing that in the case of environmental protection and climate change, formidable incomplete information problems and the global nature of needed policies make the simple "market failure" analysis and corresponding policy predictions not as useful as they might be in other areas. However, the question of the proper role of IP protection in the case of green technologies still remains.

[3] For a review of the relevant literature see Hall and Helmers [10].

[4] For IBM, see ⟨http://www.ibm.com/ibm/environment/initiatives⟩; for Xerox, see⟨http://www.xerox.com/corporate-citizenship/2011/sustainability. html⟩; for Bosch, see ⟨http://www.bosch.com/en/com/sustainability/sustainability_at_bosch.html⟩.

[5] In this case, firms could attempt to license out the patents. However, as reviewed by Arora and Gambardella [2], there are a number of important barriers to licensing out technology, in particular technology that requires further development and investment. For sellers it may be difficult to identify potential buyers and even when a potential buyer has been found, agreeing on a licensing contract for an invention may be difficult in light of technological and commercial uncertainty. Survey evidence on the licensing behavior of a sample of patenting European and Japanese firms supports the argument that identifying licensees constitutes the main barrier to licensing out ([32]). If these perceived costs of licensing out the pledged technologies exceed the expected benefits, firms may favor pledging a patent to the EcoPC over licensing it.

[6] More precisely, the EcoPC website lists 121 patent numbers. These 121 patent numbers correspond to 90 equivalent groups containing 94 unique priorities, and the total number of equivalent patents is 238. Precise definitions of these concepts are given later in the paper. The firms that have contributed to date are Bosch, Dow, DuPont, Fuji-Xerox, IBM, Mannesmann, Nokia, Pitney Bowes, Ricoh, Sony, Taisei and Xerox. Note that the patent owned by Mannesmann was absorbed and pledged by Bosch, but we nevertheless treat Mannesmann as a separate entity in our analysis. The EcoPC announced on July 1 2010 that Hewlett Packard (HP) has joined the commons and on July 25 2011 Hitachi joined. Yet, we omit HP and Hitachi in our analysis as our core data predates their entry into the commons.

[7] In fact, the 94 unique priorities accounted for by these patents are 0.02 percent of the priorities claimed by these firms between 1989 and 2005. The share ranges from 0.10 percent for Xerox to negligible for Ricoh, Sony, Nokia, and Fuji Xerox.

innovations than otherwise? In particular question (c) is interesting in light of the broader debate on the role of IP in the diffusion of environmental and climate-change related technologies. The EcoPC initiative provides a unique opportunity to study what happens to technology diffusion if valid patent protection is effectively removed from the pledged technologies.

The question of whether the EcoPC scheme achieves its objectives is directly linked to firms' underlying motivations to pledge their patents to the EcoPC. As will be explained in detail in Section 2, firms maintain ownership of their pledged patents, which implies that they have to bear the recurrent costs associated with patent ownership in the form of renewal fees. It is, therefore, far from obvious which benefits accrue to firms from the EcoPC scheme that outweigh the direct (e.g., renewal fees) and indirect (e.g., management time) financial costs associated with keeping pledged patents in force. Therefore, understanding firms' motives to pledge and keep patents in force sheds light on the effectiveness and sustainability of the commons as a hybrid form of appropriation in addressing both the knowledge and environmental externalities involved in green innovation.

To answer these questions, the present paper explores the characteristics of the patents that have been contributed to the EcoPC and compares them to two other sets of patents: (1) patents held by the pledging firms that are not donated to the commons and (2) a randomly drawn set of patents in the same technology (which also share priority year and authority with EcoPC patents). The first comparison sheds light on the question of where these patents fit in the firms' patent portfolios and hence give some indication on firms' underlying motivations to pledge these patents. Whereas the second informs us about how the value of these patents compares with other patents that protect similar technologies and that have not been donated to the commons. This comparison also provides information on the impact of the commons on technology diffusion and its potential to induce follow-on innovation by third parties.

However, given the short amount of time the EcoPC has been in place, some of the answers will be of tentative nature; we nevertheless believe that a detailed study of the pledged patents will provide insights into the open innovation-patenting relationship in the green technology area, insights that may also be useful in other areas where open innovation exists side-by-side with IP protection.

We begin the paper with a discussion of the history and detailed operation of the EcoPC. Section 3 describes the data used in our analysis. Section 4 reviews different theoretical motivations for firms to pledge their patents related to environmental protection. Section 5 provides a descriptive analysis of the characteristics of the EcoPC patents and Section 6 discusses the corresponding regression results. Section 7 discusses our approach to investigating the effect of the non-assertion pledge on technology diffusion and innovation and shows the results of our analysis. Section 8 concludes.

2. The eco-patent commons

The creation of the not-for-profit initiative EcoPC is quite recent, in January 2008. It was established by IBM, Nokia, Sony, and Pitney Bowes in cooperation with the World Business Council for Sustainable Development (WBCSD) and it allows companies to pledge patents that protect green technologies. Companies as well as individuals can join the commons by pledging at least one patent.[8] Any patent is welcome that protects a technology that confers directly or indirectly some environmental benefit—so-called green patents. "Green" is defined by a classification listing International Patent Classification (IPC) subclasses that are considered to describe environmentally friendly technologies. Yet, there appears to exist considerable flexibility as long as a pledging firm can show some (direct or indirect) environmental benefit of the pledged patent. In fact, as we show later, many of the patents contributed appear to be directed towards mitigating environmental damage from manufacturing or cleaning up after such damage.

"Pledge" in this context means making patents available for use by third parties free of charge.[9] The pledge is a legally binding commitment that prevents EcoPC member companies from enforcing any pledged patent. The ownership right remains with the pledging party which distinguishes the EcoPC from conventional patent commons. This also implies that the non-assertion pledge cannot be treated as a patent donation and hence the pledged patent is not deductible from a company's taxable income. Potential users do not have to specifically request a license; any pledged patent is automatically licensed royalty-free provided it is used in a product or process that produces some environmental benefit. This royalty-free access (users do not even have to notify EcoPC member companies if they use a pledged invention) distinguishes the patent commons from a patent pool. In a patent pool, patents are shared among members of the pool, often to resolve patent gridlocks that may be related to technology standards.[10] Outsiders have to negotiate and acquire licenses to use patents contained in the pool.

While a pledge is in principle irrevocable,[11] there is a built-in mechanism to safeguard a pledging firm's business interests which is called "defensive termination". This means that a pledging firm can "terminate" the non-assertion pledge if a third party that uses a pledged patent asserts its own patent against the pledging company. The possibility to invoke

---

[8] According to the "Ground Rules" (http://www.wbcsd.org/web/projects/ecopatent/EcoPatentGroundRules.pdf), also "any worldwide counterparts" to the pledged patent are considered to be subject to the non-assertion pledge, i.e., any equivalents to the pledged patent.

[9] Third parties comprise anyone interested in the patented technology and *not* only other firms that are part of the commons.

[10] See for example Lampe and Moser [21] who look at the first patent pool in the US in the sewing machine industry. See also Layne-Farrar and Lerner [23] for evidence on modern patent pools.

[11] The "Ground Rules" (http://www.wbcsd.org/web/projects/ecopatent/EcoPatentGroundRules.pdf) stipulate that "[a] patent approved for inclusion on the Patent List cannot be removed from the Patent List, except that it may be deleted for so long as the patent is not enforceable." However, firms obviously

"defensive termination" does not apply to other pledging firms in the commons unless the primary IPC of the asserted patent is on the commons IPC classification list. The fact that companies retain ownership rights also means that they have to bear the cost of maintaining the IP right, that is, they must pay any fees required to keep the patent in force.[12]

The initial members of the commons when it was launched in January 2008 were IBM, Nokia, Pitney Bowes, and Sony. In September 2008, Bosch, DuPont, and Xerox joined. Ricoh and Taisei entered the commons in March 2009 and Dow Chemical and Fuji-Xerox in October 2009. Its newest members, Hewlett Packard (HP) and Hitachi joined in July 2010 and July 2011 respectively, but are excluded from our analysis.[13] The recent entry of HP and Hitachi into the commons underlines the fact that the project continues to be active and to attract new members. All patents pledged to the EcoPC are listed in an online data-base (the data base is reproduced in Appendix A1 available at the journal's online repository of supplemental material, which can be accessed from http://www.jeem-supplemental.org).

The EcoPC is currently the only initiative of this type,[14] although Creative Commons in collaboration with Nike and Best Buy has set up a similar initiative, the GreenXchange.[15] In this new initiative (in contrast to the EcoPC), pledging firms can choose whether to charge a fee for the use of a pledged patent. Contributing firms can also selectively deny other firms the use of a pledged patent. In addition, registration of users of contributed patents is mandatory. As a matter for future research, it would be interesting to investigate whether the difference in institutional design of the GreenXchange has any effect on the achievement of the objective that both commons share.

To reiterate the official objective of the EcoPC laid out in the Introduction: the EcoPC aims to promote the sharing of technologies and that "protect and benefit the environment" and thus to assist in environmental protection for the common good. The initiative targets green patents that are neither used nor represent "an essential source of business advantage" to their owners. Hence, the commons does not require firms to sacrifice patents of particular business value for the common good. It should, therefore, attract those patents that are neither "worked" nor confer a strategic value to the company even as a "dormant" property right (see also Section 4). The initiative endeavors to emphasize potential business benefits for firms from participating in the commons: it can serve as a way of diffusing a technology and potentially lead to new collaboration and business opportunities. But most importantly, participation in the scheme guarantees broad public visibility considering the great deal of (mostly positive) attention in the press the initiative has received so far (NY Times 31 October 2009; Wall Street Journal 14 January 2008; WIPO Magazine April 2009) and innumerable postings and discussions in blogs and climate-change/open-innovation online forums.

However, a number of these press articles and blog postings contest the value of the initiative. For example, the Wall Street Journal (14 January 2008) notes that the environmental benefit is not obvious for some of the EcoPC patents. As a case in point, the press article provides the example of a patent pledged by Pitney Bowes "that protects electronic scales from being damaged when they are overloaded."[16] In a review of the EcoPC initiative, Srinivas [30] lists a number of potential problems with the initiative. He asserts that the technologies protected so far by patents in the EcoPC "have a very limited application in the further development of technologies in key sectors." However, he does not provide any proof for this assertion. Related to this, he claims that more important players in the market for climate-change related technologies have to join the commons in order to make it an effective tool for the dissemination of relevant technologies. He is also skeptical that simply providing royalty-free access to single green patents will have a significant impact on the diffusion of green technologies as most technologies are covered by multiple patents which are not included in the commons. Cronin [6] argues in her article in Greenbiz[17] that the patents contained in the EcoPC are of little value as they protect outdated technologies. She also asks the natural question of why private companies would give something valuable away for free. In order to make the EcoPC more valuable, Cronin suggests that it should include novel non-patented inventions that have not been made public before, presumably because they were protected via (trade) secrecy. This could be done inexpensively in the form of defensive publications, which are currently not part of the EcoPC.

(*footnote continued*)

can withdraw from the commons at any point in time, although even in this case "[v]oluntary or involuntary withdrawal [from the commons] shall not affect the non-assert as to any approved pledged patent(s) the non-assert survives and remains in force."

[12] When a patent is applied for at the EPO, renewal fees must be paid to the EPO beginning the third year counted from the date of filing until the patent is granted. Once the patent has been granted, renewal fees have to be paid to the national offices separately in which the patent has been validated. Renewal fees at the EPO for 3rd and 4th year from the date of filing amount EUR 420 and EUR 525 respectively and keep increasing to EUR 1420 beginning 10th year from the date of filing (see Supplement 1 to OJ EPO 3/2010). Renewal fees in national offices vary substantially, as of August 2010, for example in the UK, fees increase during the 20 years of patent validity from GBP 70 to GBP 600, whereas in Germany, fees increase from EUR 70 to EUR 1940 (EPO National law relating to the EPC, May 2011). Maintenance of a patent family can thus be quite costly if annual fees have to be paid at several patent offices. Contrary to the EPO and European national offices, at the USPTO, renewal fees are not payable annually. At 3.5 years, the maintenance fees due amount to US\$ 980, at 7.5 years to US\$ 2480 and at 11.5 years to US\$ 4110.

[13] HP has pledged three patents, Hitachi only a single patent.

[14] The World Intellectual Property Organization (WIPO) recently (in October 2011) established a patent commons for patents relevant for neglected tropical diseases. Under this initiative, called WIPO Re:Search, a number of multinational pharmaceutical companies make selected patents available royalty-free.

[15] For more details on the GreenXchange initiative see [9].

[16] This patent is a bit of an exception. It seems that overload is likely to cause damage to the load cell, a core component of highly sensitive and accurate electronic scales. The invention, therefore, avoids the need for frequent replacement of the load cell and hence helps avoiding environmental waste.

[17] ⟨www.greenbiz.com⟩

However, the issue is even more puzzling, because firms actually pay to provide royalty-free access to their patents. As pointed out by Bucknell [5] in an article for Think IP Strategy,[18] firms could instead allow a patent to lapse by simply not paying renewal fees and to communicate to the public that the main motivation for doing so is to allow third parties access to the invention and hence to spur its diffusion. The relevant question, therefore, is why firms would find it worthwhile to offer non-exclusive royalty-free licenses to a set of patents while simultaneously incurring the cost of keeping them in force? Why not simply allow the patents to lapse, effectively publishing the contents defensively? Is the value of possible defensive termination against future threats that large?

In the academic literature, so far, only Van Hoorebeek and Onzivu [31] discuss the EcoPC initiative. They regard it as a private response to calls by mostly developing countries for increased climate change related technology transfer. As such, the EcoPC initiative may help deflect increasing pressure exerted by developing countries to apply TRIPS provisions including compulsory licensing or even denying patent protection to specific climate change related technologies. But for this strategy to be viable, patents pledged under the EcoPC initiative should protect enforceable and "valuable" technologies, an assumption that Van Hoorebeek and Onzivu [31] do not investigate in their qualitative discussion.

More generally, there has been some discussion in the strategic management literature on patent pledges in the context of software. For example, firms may choose to pledge patents to mold the wider appropriability regime that governs their business activity [1]. Using software patents as an example, the authors argue that firms which stand to profit from the open source software concept through the production of complementary assets, such as IBM and Nokia, choose to unilaterally pledge patents in order to create an appropriability regime conducive to the open source movement. The establishment of a patent commons would seem consistent with this reasoning as it would enable firms to address the collective action problem involved in shifting the appropriability regime. Since the EcoPC firms are not major players in the market for green technologies, shifting the appropriability regime governing green technologies might thus even be beneficial as it could harm potential competitors and induce sales of complementary assets provided by EcoPC firms. Nevertheless, the assumption underlying this argument is again that firms pledge "valuable" patents.

Biotechnology, a research field in which IP protection of key technologies appears to have detrimental effects on innovation [24], offers another example of a similar initiative: the BiOS (Biological Open Source) initiative by the not-for-profit institute CAMBIA. In the case of BiOS, firms may use patented technologies royalty-free but agree to "share with all BiOS licensees any improvements to the core technologies as defined, for which they seek any IP protection" and "agree not to assert over other BiOS licensees their own or third-party rights that might dominate the defined technologies" ([16]: 459). The strength of this initiative appears to rest largely on the value of the IP rights available under BiOS licenses.

In summary, the EcoPC initiative provides an institutional design that allows easy access to patented technologies, which may confer some direct or indirect environmental benefits. It is, however, far from obvious whether the pledged patents protect any valuable green technologies as the motives for firms to pledge valuable green patents and keep them in force are not clear-cut.

3. Data

The online data Appendix A describes in detail how we created our EcoPC dataset and control samples. We started with the list of 121 patents contributed to the EcoPC by the 12 contributing firms which is available on WBCSD's website.[19] We then used the October 2011 edition of EPO's PATSTAT to draw the following samples of patents:

1. All of the patents with the same set of priority documents as the EcoPC patents, i.e., all EcoPC equivalents.[20]
2. Control (1) sample: all patent applications worldwide that were made by the 12 EcoPC firms.
3. Control (2) sample: all patent applications worldwide with the same IPC symbol, priority year and priority authority as an EcoPC patent. In addition, we restrict this sample to patents applied for by firms (i.e., not by individuals/public research institutions).

A number of complications arose in performing these tasks. First, PATSTAT is based on published applications, whether or not the patents have been granted. This is an advantage because most of our EcoPC patents are of fairly recent date and may not yet have been granted. However, not all US applications are published at 18 months, especially in the earlier part of our sample. Even if they are published, it appears that some firms leave the assignment of ownership off the application until the patent issues, so we will not find all the patent applications that correspond to a given firm. When we use a matched control sample later in the paper (Section 7), this is no longer a problem because in that case we are able to verify the owner (s) manually.

A second problem is missing priorities. Many of these patents have multiple equivalents, which are patents applied for in several jurisdictions on the same invention. We prefer to perform our analysis using only a single observation for each

---

Table 1
Patents contributed to the commons compared to the contributing firms' portfolios.

	All applications and equivalents				Unique equivalent groups			Average family size in dataset	
	Date entered the commons	EcoPC patents	Total patents	Share (%)	Eco-patents	Total patents	Share (%)	EcoPC patents	Total patents
DuPont	Jan-08	43	40,761	0.105	11	11,546	0.095	3.91	3.53
IBM	Jan-08	53	100,099	0.053	29	57,014	0.051	1.83	1.76
Mannesmann	Jan-08	2	7027	0.028	1	2467	0.041	2.00	2.85
Nokia	Jan-08	3	51,621	0.006	1	12,111	0.008	3.00	4.26
PitneyBowes	Jan-08	7	4589	0.153	2	2018	0.099	3.50	2.27
Sony	Jan-08	4	184,093	0.002	4	118,578	0.003	1.00	1.55
Bosch	Sep-08	52	91,942	0.057	23	30,047	0.077	2.26	3.06
Xerox	Sep-08	56	28,491	0.197	13	12,509	0.104	4.31	2.28
Ricoh	Mar-09	1	109,978	0.001	1	96,016	0.001	1.00	1.15
Taisei	Mar-09	2	6924	0.029	2	6767	0.030	1.00	1.02
Dow	Oct-09	9	14,629	0.062	1	3898	0.026	9.00	3.75
FujiXerox	Oct-09	6	43,001	0.014	2	36,993	0.005	3.00	1.16
Total		**238**	**683,155**	**0.035**	**90**	**389,964**	**0.023**	**2.64**	**1.75**

"invention," preferably the priority application. However a large number of patents have missing priorities and in this case we simply allowed the patent to serve as its own priority. This may mean that we effectively keep the patent as a single patent with no equivalents.[21]

A related problem is that some applications have multiple priorities and some patents serve as priority patents for multiple applications to the same authority, making the assignment of a unique priority application to each application problematic. Although these problems afflict only a minority of applications, they do exist for a subset of our EcoPC patents. For example, US priority patent application 57503704 from 2004 serves as a priority patent for 9 US patent applications. Of these 9 applications, 2 have an additional 4 priority patents at the USPTO in 2004, and 7 have one additional priority patent, also at the USPTO in 2004. Not surprisingly, the assignee for all these patents is DuPont Corporation, a chemicals firm: the pattern of multiple interlocking priorities is much more common in chemicals than elsewhere. Our solution to this problem is to define an invention as an equivalent group of patents and to use the earliest priority application as the priority patent.[22] In the case described above, there are two groups, one consisting of the first 2 applications, which share a common priority set (US 2004 53681904, 54997804, 57503704, 58478504, and 53745304), and one consisting of the second 7, which also share a common priority set (US 2004 57503704 and 58478504). Thus although there are 94 unique priorities among the EcoPC patents, there are only 90 unique equivalent groups. Table 1 shows the various counts for both the EcoPC patent and the control samples.

Ideally we would like to study these patents at the level of unique inventions, i.e., priorities. However, owing to the missing priority problem identified above and the overlapping priorities which imply that families, i.e., equivalent groups, are the correct unit of analysis (and introduces a new problem of identifying a unique priority patent for each family), we are not able to do this precisely. We verified that the analysis is not very sensitive to our choice by re-estimating some of our models using all 238 of the EcoPC patents, and weighting the observations by the inverse of the equivalent group or family size, effectively down-weighting those patents that have many incarnations. These estimates are available on request, but using all equivalents seldom made much difference to the results. We do cluster the standard errors by equivalence group, to allow for within-group correlation of the errors.

4. Which patents do firms pledge?

Constructing an estimable model of the patent donation process is challenging for two reasons. First, although we observe considerable detail about the patents being donated, they form a very small part of the firm's patent portfolio (less than 1 percent). This means that modeling at the firm level, where we have non-patent information available, will not yield a useful empirical framework. Second, at the patent or invention level, we do not observe important decisions made prior to donation—We only observe the decision to donate the patent. We discuss this problem explicitly below, using the firm's patenting decision tree to guide us in developing an econometric model.

Fig. 1 shows the decision tree of a firm with an invention, that has to decide whether to patent the invention, and then whether to "work" the patent, abandon it, or pledge the patent to the EcoPC. At each decision point represented by a circle, new information about the invention and its value to the firm is revealed. That is, after a firm decides to patent the invention, it may learn something which implies that the patent is no longer necessary, or the invention is not useful.

---

[21] We have checked this assumption using the equivalents data constructed by Dietmar Harhoff and co-workers and found that it introduces very little error into the data. All the additional equivalents for our EcoPC patents that were found this way were for unpublished patent applications, which are not in our sample. See http://www.inno-tec.bwl.uni-muenchen.de/forschung/forschungsprojekte/patent_cit_project/index.html for the equivalents data.

[22] Note that our definition is essentially the same as the first (equivalents) definition in Martinez [25]. See also online Appendix A2 for more details.
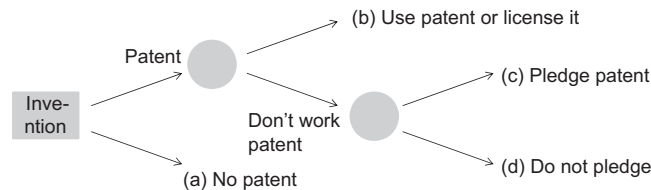
Fig. 1. Firm's decision tree.

The pledging decision may also be influenced by new information that suggests a benefit to encouraging others to use the invention.

Unfortunately, we only observe some of the decisions in Fig. 1. Among the four final outcomes (*a*—no patent, *b*—work the patent, *c*—pledge the patent, *d*—neither work nor pledge the patent), we observe only *c* and the combination of *b* and *d*. This limits our ability to build a structural model of the decision process. Conditional on patenting, we can, however, conjecture the following based on our discussion in Section 2:

1. The firm is more likely to work the patent if it is valuable to the firm, if more resources were invested in acquiring it, and if it is related to the firm's own line of business or technology expertise.
2. The firm is more likely to pledge a patent if it is environmentally friendly, if it is less related to the firm's own line of business or technology expertise, and if it is not suitable for licensing, or if the transaction costs of licensing are too high.

Taken together, this suggests that a firm's pledged patents will be less valuable to the firm, more "green", and less related to the firm's patent portfolio. We note also that in some cases (those where the patented invention is perhaps not useful to the firm itself), the choice will be between licensing the patent by negotiating a contract with potential licensees and royalty-free licensing without a contract. This choice is not precisely observed (since it is confounded with the choice to use the patent in-house), but it is of interest. We expect that royalty-free licensing (donation or pledging) will be chosen when there are many (unknown) potential licensees and the costs of finding them and negotiating licenses is simply too high and uncertain, and the public relations or other benefits of donation exceed these costs.

We might also expect that donated patents are less likely to be prosecuted aggressively if they have not yet issued, and that they are less likely to remain in force. If firms (ab)use the commons purely for public relation motives, we would expect to see pledged patents to lapse, i.e., not to be in force, shortly after entering the EcoPC because presumably most PR benefits are reaped at the moment when the pledge is announced.

Hence, while a firm's decision to 'work' a patent remains unobserved, we can nevertheless deduce from the characteristics of the pledged patents themselves (notably their legal status) as well as relative to other patents held by the same firm or patents in the same technology field what a firm's underlying motives for pledging patents are and hence what type of patent from a firm's patent portfolio is pledged.

5. Descriptive statistics

In this section of the paper we present some basic information about the patents contributed to the commons: their ages, legal status, grant lag, priority authorities, family sizes, the technology areas, and the firms contributing. In combination with the regression analysis in Section 6, this allows us to address the first two questions posed in the introduction: are the patented technologies indeed related to environmental protection? Are the patents that protect these technologies valuable?

Table 1 shows the number of patents contributed by each of the 12 firms. The first panel shows all the patents and their equivalents, a total of 238 patent applications, and the second panel shows the unique 90 equivalence groups that correspond to these patents. Table 1 shows that the donated patents are a tiny share of the firms' portfolios (less than 0.1 percent) and that the majority of the patent families (76 out of 90, or 84 percent) have been contributed by just four firms: Bosch, DuPont, IBM, and Xerox. In Appendix Table A3 we show that in almost all cases the priority patent was applied for at the USPTO, the German patent office, or the JPO, and in most cases at the office corresponding to the headquarters of the applicant. Table 1 also shows the date that each firm entered the commons; to the best of our knowledge, this is also the date that all their patents were contributed. The dates are all quite recent, so we have only three to four years to observe these patents after donation, with the inevitable consequence that our analysis will be preliminary, but we believe it is useful to set the stage for subsequent analysis performed after some more time has passed.

Table 2 gives a rough idea of the technologies that have been contributed. This table is based on a reading of the abstract and written description of these patents, with a special focus on the description of the problem to be solved, in order to determine their likely application. Two related observations about the data in this table suggest themselves: first, only slightly more than one-third of these patents fall into classes that are designated as a clean technology class by the

Table 2
Rough categorization of EcoPC technologies.

Technology	Not in OECD sample	In OECD sample	Total
Not clear	1	0	1
Clean manufacturing	23	2	25
Clean up soil and groundwater	0	16	16
Electric auto related	1	1	2
Energy efficiency (mostly autos)	12	2	14
Global warming (fluorocarbons)	5	0	5
Pollution	7	8	15
Detection of environmental damage	5	0	5
Recycling (mostly disks)	3	4	7
Total	**57**	**33**	**90**
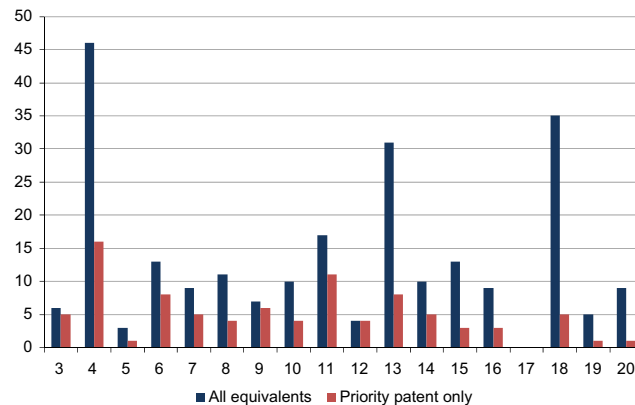
Fig. 2. Age of eco-patents in years at time of donation (relative to priority date).

OECD-EPO definition ([18])[23] Second, many of them seem to be related to environmental cleanup or clean manufacturing, and only tangentially to new environmentally-sound technology creation.[24]

The ages of the contributed patents at the time of their donation vary widely. A few are old and nearing the end of their life, but many have substantial statutory life remaining (Fig. 2). Age is measured as the exact date the owning firm joined the commons less the exact priority date of the patent. In general, the statutory life of the patents will be twenty years from the date of application (which often coincides with the priority date), and we find a range from 3 years to 20 years, with a peak at 4 years of age. This is suggestive, as most patents are granted by the time the application is four years old, and this age also corresponds roughly to the time when some uncertainty about potential value of the invention is likely to have been resolved ([22])[25] In Fig. 3, we show the priority year distribution of the contributions as a share of the 12 firms' patents (Control 1 sample) and also as a share of patents in the relevant IPC classes (Control 2 sample). Both are roughly flat but with high variability, and an observable increase in contribution rates for the priority years 2004 and 2005.

One of the questions raised in Section 2 was whether and why firms would pay to keep a patent in force once it was contributed to the commons. Because many of the donations are quite recent, it is difficult to observe whether firms have chosen to pay renewal fees on their patents after they have been donated. It is also the case that many of these patents have not even been granted at the time of our study. In Table 3, we look at the legal status of all the equivalent patents, where we have collected the data manually from the relevant patent offices as described above (as of February/March 2011). It appears that almost half of these patents have been granted and are still in force, 2.5 percent are pending, and 40 percent are withdrawn, rejected by the relevant office, lapsed or have expired.[26] We also looked at the shares weighted by the inverse of the family size and found that 64 percent are in force, about 2 percent are pending, and 28 percent are not in force. So in fact, it does appear that in some cases the applicants have chosen to abandon the donated patents before their statutory term has expired, or have chosen not to prosecute them aggressively. However, the difference in the weighted results

---

[23] The relevant IPC classes are available at ⟨http://www.oecd.org/document/55/0,3343,en_2649_34333_43383927_1_1_1_1,00.html⟩

[24] There is one patent for which we could not ascertain the environmental benefit. The patent is entitled 'Image Forming Device' and has the objective '[t]o prevent a user from getting into a dangerous situation caused by fault and breakage due to use exceeding the working limit of a cartridge.' According to personal communication with WBCSD, the "patent describes a device encouraging the user to recycle cartridges and reduce natural resource consumption."

[25] EPO patents typically take longer to grant than four years, but are relatively underrepresented in our sample, which consists primarily of USPTO, German patent office, and JPO patent applications and grants.

[26] As best we can determine, the NA category corresponds to those patent applications that have not yet been examined by the relevant office, either because they are newer, or, in some cases, because examination was not requested by the applicant. The patent offices concerned are Japan, Russia, and Mexico.
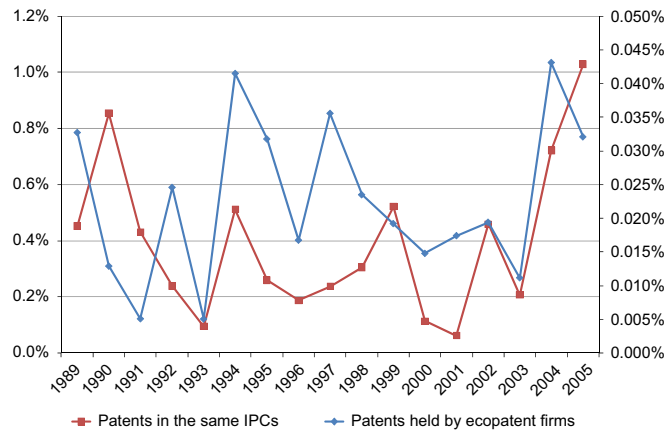
Fig. 3. Share of patents contributed, by earliest priority year for the equivalence group.

Table 3
Legal status of EcoPC and Control patents.

	Eco PC		Controls	
	Number	Share (%)	Number	Share (%)
In force	117	49	194	41
Nonpayment of fees	37	16	94	20
Expired	19	8	5	1
Withdrawn	23	10	70	15
Rejected	16	7	25	5
Unexamined/Pending	4	2	32	7
Published in National Office	2	1	14	3
NA	20	8	39	8
All	**238**		**473**	

Legal status as of February/March 2011.

suggests that in many cases, at least one of the equivalents is still in force[27]. Additional information is shown in Table A4 in the appendix, which provides a breakdown of the data by pledging company. We also found that firms are more likely to maintain the patents in the US, Germany, or at the EPO, and less likely in other jurisdictions. Table 3 also shows the legal status of a matched control sample of patents in the same technology classes as the EcoPC patents; this matching sample is discussed in more detail in Section 7. The comparison shows that the share of patents in force is larger for the EcoPC sample. In fact, 70 percent of the priorities pertaining to unique equivalent groups are still in force relative to 38 percent in the control sample (not shown).

The descriptive statistics provided in this section suggest that a substantial share of EcoPC patents have been granted and are maintained in force. In any case, most patents that enter the commons are young and most of their statutory lifetime remains. The technologies covered by the EcoPC patents appear to be related to environmental protection, although this is a matter of interpretation as the OECD clean technology definition categorizes only a third of the EcoPC patents as "green". We also showed that the EcoPC patents account for tiny shares in EcoPC firms' patent portfolios. Considering the size of the patent portfolios held by firms such as IBM or Sony, this is hardly a surprising result.

6. Characteristics of donated patents

In this section of the paper, we take a look at the characteristics of the EcoPC patents and compare them to our two control samples, first using univariate analysis and then via multivariate probit regressions. The characteristics we look at are the usual bibliometric statistics available in patent data that have been shown to be related to patent value (e.g., [13]):

---

[27] In fact, 16 of the 90 equivalence groups have no patent that is still in force, 56 have one such patent, and 18 have more than one.

- The number of inventors listed on the application, which is a measure of patent value and also related to the amount of resources invested in the invention[28]. This variable is occasionally missing from PATSTAT, and we add a missing value dummy when that is the case.
- The family size as given by DOCDB, which is a proxy for the value of the invention.[29]
- The number of citations received worldwide by April 2010, another proxy for value, and for diffusion.
- The number of references to other patents, which may be related to the extent to which this invention is derivative of others.
- The number of references to the non-patent literature, a proxy for closeness to science.
- The number of IPCs in which the patent has been classified, sometimes used as a proxy for the scope or breadth of the invention.
- Whether the patent has been granted, and the lag between the application date and the grant date. The grant lag has been shown to be positively related to other value measures by Johnson and Popp [17].

We also include a dummy that indicates whether the patent falls in one of the OECD green technology patent classes [18]. Finally, when comparing our patents to the others held by the contributing firms, we include a measure of their similarity to the other patents in the firm's portfolio. This measure is the sum of the relative frequency of a patent's IPC codes in the firm's portfolio. It ranges from zero to 0.79; higher values correspond to higher similarity.

Table 4 shows the means, standard deviations, minima, and maxima of these variables for the EcoPC patents and the two control samples. The table also shows a simple *t*-test for differences in the means, and a nonparametric ranksum test for differences in the distributions of each variable across the samples. Compared to the other patent applications by these firms (Control 1 sample), EcoPC patents have more inventors, a larger family size, more backward citations, more non-patent references, are classified in more IPCs, and are much more likely to fall in the OECD green technology classes (not surprisingly). However, they have the same pattern of forward citations, suggesting that the knowledge they contain is not diffusing faster than that of the patents retained by the firms. They are also clearly more distant from the firm's portfolio than the other patents. Compared to patents in the same classes (Control 2 sample), however, the EcoPC patents have smaller family sizes, but more backward citations. They are also classified in many fewer IPCs, suggesting that they are narrower than other patents in these classes. For those patents that have been granted, the grant lag for EcoPC patents is shorter than that for either control sample, and correspondingly, they are more likely to have been granted. Interestingly, they are more likely to be classified as green technology according to the OECD definition than patents in the same 4-digit classes.

Table 5 takes a multivariate look at the difference between EcoPC patents and the other patents applied for by the 12 EcoPC firms. This table shows the results of a probit regression for the probability that a patent is an EcoPC patent as a function of the patent characteristics, the priority year, dummies for the one-digit IPC, and dummies for the four leading firms (Bosch, DuPont, IBM, and Xerox). The standard errors for these regressions are robust to heteroskedasticity and grouped by equivalence group. The EcoPC patents are clearly more likely to be green-tech patents and to be far from the firm's portfolio of technologies. They also have a larger family size, suggesting that they were viewed as more valuable by the firm at the time of application. However, the negative coefficient for forward citations suggests that this value was not confirmed as time passed. The remaining variables are insignificant, partly because their standard errors are quite large due to the correlation among them. The conclusion is that with the exception of the technology with which they are concerned and their closeness to the firm's portfolio, these patents are essentially indistinguishable from other patents held by the firm.

Table 5 also performs a similar exercise using the second control sample, patents in the same IPCs as the EcoPC patents, i. e., comparing patents protecting in principle similar technologies. As in the case of the first control sample, we find that the EcoPC patents have fewer forward citations and (possibly) more backward citations than other patents in their classes. They also have significantly fewer IPC classifications, implying that they are narrower, and of course are more likely to be in one of the OECD green technology classes. Although the grant lag is insignificantly negative, they are more likely to have been granted, which suggests a shorter grant lag and therefore lower value. Controlling for other value-related characteristics may have rendered the grant lag insignificant.

The following section investigates whether pledging the property rights has had a discernible impact on the diffusion of the protected technologies.

7. Technology diffusion and follow-on innovation

The descriptive statistics and the regression analysis described in Sections 5 and 6 above suggest that EcoPC patents protect environmentally-related technologies that are not of obvious lower value than other patents held by the pledging firms. The ensuing question is whether pledging these patents, i.e., effectively removing patent protection from patents that

---

[28] Sapsalis et al. [29] find the number of inventors to be positively correlated with patent value for patents assigned to companies. The authors argue that a larger research team (i.e. a larger number of inventors), which implies a larger amount of resources, suggests higher expected profits from the research project.

[29] See for example Lanjouw et al. [22] and Harhoff et al. [13].

Table 4

Statistics on regression variables.

Simple statistics for patents owned by firms contributing EcoPC patents (priority years 1989–2005)

Variable	Mean[a]		Std. Dev.[a]		T-test	z-test	Minimum		Maximum	
	Ecopatents	Other	Ecopatents	Other	Difference	Ranksum	Ecopatents	Other	Ecopatents	Other
Number of inventors	2.957	2.635	0.599	0.563	**2.1**	**3.8**	0	0	9	29
Family size	4.926	3.514	0.595	0.604	**6.2**	**8.9**	1	1	14	70
Forward citations to 2011	1.672	1.640	0.959	0.910	0.2	0.3	0	0	82	825
Backward citations	2.228	1.733	1.119	0.996	**2.4**	**4.0**	0	0	49	189
Non-patent references	1.255	1.154	0.552	0.463	1.6	**3.0**	0	0	26	123
Number of IPCs	4.693	4.195	0.478	0.506	**2.6**	**3.8**	1	1	14	92
Grant lag in months[b]	40.44	46.71	0.761	0.637	**−2.1**	**−2.7**	1	1	178	240
D (patent was granted)	0.756	0.515	0.430	0.500	**9.7**	**7.5**	0	0	1	1
D (OECD greentech class)	0.332	0.011	0.472	0.105	**7.4**	**46.8**	0	0	1	1
Similarity measure	0.051	0.133	0.070	0.115	**−12.8**	**−13.1**	0.000	0.000	0.331	0.790
D (inventors missing)	0.139	0.133	0.346	0.340	0.2	0.3	0	0	1	1

Based on 238 observations for EcoPC patents and 683,155 for other patents owned by the same firms.
D (.) denotes a dummy (zero/one) variable.

Simple statistics for patents in the same classes as EcoPC patents (priority years 1989–2005)

Variable	Mean[a]		Std. Dev.[c]		T-test	z-test	Minimum		Maximum	
	Ecopatents	Same classes	Ecopatents	Same classes	Difference	Ranksum	Ecopatents	Same classes	Ecopatents	Same classes
Number of inventors	2.957	2.991	0.599	0.634	−0.2	0.0	0	0	9	38
Family size	4.926	6.331	0.595	0.788	**−4.6**	**−5.2**	1	1	14	102
Forward citations to 2011	1.672	1.593	0.959	0.956	0.6	1.2	0	0	82	711
Backward citations	2.228	1.750	1.119	1.066	**2.4**	**4.2**	0	0	49	190
Non-patent references	1.255	1.353	0.552	0.808	−1.5	−0.2	0	0	26	164
Number of IPCs	4.693	7.267	0.478	0.705	**−10.0**	**−9.7**	1	1	14	173
Grant lag in months[d]	40.45	47.85	0.761	0.690	**−2.4**	**−3.1**	9	1	178	218
D (patent was granted)	0.756	0.523	0.430	0.499	**5.9**	**7.1**	0	0	1	1
D (OECD greentech class)	0.332	0.071	0.472	0.257	**6.0**	**15.6**	0	0	1	1
D (inventors missing)	0.139	0.148	0.346	0.355	−0.3	0.4	0	0	1	1

Based on 238 observations for EcoPC patents and 113,912 observations for others in the same classes.
D (.) denotes a dummy (zero/one) variable.
[a] Geometric mean for the first 6 variables; standard deviation of the log of the variable.
[b] For those patents that have been granted - 180 EcoPC patents and 351,787 controls.
[c] Geometric mean for the first 7 variables; standard deviation of the log of the variable.
[d] For those patents that have been granted—180 EcoPC patents and 59,597 controls.

remain in principle enforceable, has had an impact on the diffusion of the protected technologies and has spurred the development of new innovation which is based on the pledged patents.

7.1. Empirical approach

There are at least two challenges in assessing the effect of the commons on diffusion and innovation. First, diffusion in terms of the application and use of the protected technologies in question cannot be captured. According to the rules of the EcoPC, third parties are allowed to use pledged patents without signaling this to the patent owners. Hence, if a third party applies an EcoPC patent in a process or product, we are unable to observe this unless the third party cites the EcoPC patent in a patent application aimed at protecting the new process or product. It is important to emphasize that this may substantially undermine our ability to investigate the impact of the non-assertion pledge on pure diffusion without additional innovation for which patent protection is sought. Nevertheless, we are able to roughly gauge how serious this problem is by using data made available to us by the WBCSD on the number of webhits that patents in the EcoPC database had received by April 2011. While the information content of the data is difficult to assess,[30] it shows that 36 of the EcoPC patents had received a total of 6267 hits by April 2011. Similar to forward citations, the distribution of hits is highly skewed,

---

[30] As shown in Table A1, the WBCSD website showed only 121 patents instead of the complete set of 238 and there were a number of incorrect entries. Moreover, webhits may also simply arise from journalists and academics instead of potential users. Obviously, these hits are only available post-pledge, which means we cannot rely on them to assess the impact of the EcoPC on diffusion.

Table 5
Determinants of the probability a patent is an EcoPC patent.

	Compared to other patents held by the same firm		Compared to other patents in the same classes	
	Coefficient	Std. error	Coefficient	Std. error
Log number of inventors	−0.043	0.100	0.088	0.110
Log family size	0.166	0.092*	−0.037	0.076
Log forward citations to 2011	−0.050	0.029*	−0.089	0.037**
Log backward citations	0.035	0.028	0.050	0.028*
Log non-patent references	0.023	0.039	−0.053	0.036
Log number of IPCs	−0.125	0.101	−0.469	0.103***
Log grant lag in months	−0.003	0.048	−0.038	0.047
Dummy (patent has been granted)	0.177	0.202	0.472	0.197**
Dummy for OECD greentech class	0.979	0.102***	0.497	0.125***
Dummy for missing # inventors	−0.026	0.204	0.280	0.159*
Similarity measure	−2.255	0.646***		
Priority year dummies	yes		yes	
IPC (1) dummies	yes		yes	
Firm dummies	yes		NA	
Number of obs (Number=1)	683,393 (2 3 8)		114,150 (2 3 8)	
Pseudo R-squared	0.247		0.137	
Log likelihood	−1606.6		−1472.4	

Sample period is priority years 1989–2005.
Heteroskedastic standard errors, clustered by equivalence group.
Probit estimation by maximum likelihood.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% levels.

with a maximum of 1418 and minimum of 50 hits.[31] Interestingly, 10 out of these 36 patents also received at least one forward citation by a patent with a priority date after the pledge date, with those 10 patents receiving a total of 2854 hits, i.e., more than 45 percent of all hits. This suggests a strong positive correlation between the interest displayed by potential users as evidenced by webhits and actual diffusion evidenced by forward citations.

Second, we observe patents for at most four years after they have been pledged, which is a relatively short amount of time that the inventions protected by these patents have been freely accessible. Considering the possible long lag time in the development of new technologies based on existing patents and the common 18 month period between application and publication date, this may limit our ability to find patents that build on the EcoPC patents after they have entered the commons. To mitigate this problem, we have augmented the PATSTAT October 2011 citation data with data manually collected from Espacenet as of May 2012.

To investigate the question of knowledge diffusion, we used a research design that is similar to a differences-in-differences estimation, but one that can allow for differential citation behavior for the EcoPC patents before donation, which turns out to be important. We observe all patents before and after they have been pledged and therefore analyze whether there are statistically significant differences in the pattern of forward citations these patents receive before and after they entered the commons, comparing them to a control group of patents. If royalty-free access has had an impact on diffusion of these technologies, we would expect to see a statistically significant increase in the forward citations that the EcoPC patents have received subsequent to their pledge. As a control group, we use a set of patents matched by priority year, application authority and technology class to the EcoPC patents.

The modeling challenge in testing whether there is a change in citation frequency after patents are donated to the commons is specifying a baseline citation intensity. First, we note that in general there is an identity relating priority year t, citation year u, and citation lag s:

$$u = t + s$$

Therefore only two of the three effects are identified semi-parametrically (i.e., using dummies).[32] By itself, this is not a serious problem, since a full set of dummies for two of them allows us to capture citation behavior fairly well. However, because most of the EcoPC patents are donated during a short two-year period, we cannot identify the post-donation impact separately if we allow the EcoPC patents to have their own (freely specified) citation distribution.

Our modeling approach is therefore twofold: First, we use a fully semi-parametric model of the citation lag distribution that allows for both priority year and cite lag effects (thus implicitly also including citing year effects) to which we add dummies for the average level of EcoPC patent citations and for the level after donation to the commons. The unit of observation is therefore cites C_{is}

---

[31] The patent with most hits is pledged by Nokia and entitled "Systems and methods for recycling of cell phones at the end of life."
[32] See Hall, Mairesse, and Turner [12], inter alia, for a full discussion of the time-vintage-age problem.

per patent per citation lag, where the lag is measured by the number of years between the priority dates of the citing patent and the cited patent. Most of the values of the cites variable are quite small (about 80 percent are zero) so we use Poisson regression with standard errors robust to heteroskedasticity for estimation. The Poisson parameter λ_{is} is specified as follows:

$$\lambda_{is} = exp\left[\sum_{t=1}^{T}\alpha_t I(year=t) + \sum_{s=0}^{S}\gamma_s I(lag=s) + \delta_{eco}D_{is}^{eco} + \delta_{after}D_{is}^{after}\right] \tag{1}$$

D^{eco} is the dummy for EcoPC patents and D^{after} is a dummy for EcoPC patents after donation.

Our second approach uses a more parsimonious specification of the baseline citation lag distribution, one that is due to [15]. This model imposes a smooth distribution on the lag distribution that incorporates both the diffusion of knowledge in the patent and the decay in its usefulness. Let c_{st} be the average number of cites received by patents with priority year t and citation lag s ($c_{st}=C_{st}/P_{st}$). Then the simplest version of this model is the following:

$$c_{st} = \beta_0 f(t)e^{-\beta_1 s}(1-e^{-\beta_2 s}) + \varepsilon_{st} \tag{2}$$

$f(t)$ is an arbitrary function of the patent's priority year; we use a full set of priority year dummies and omit β_0. The β_1 parameter measures the rate at which citation declines as a function of the lag (obsolescence of the information in the patent), and the β_2 parameter the rate at which citation increases initially (diffusion of the information in the patent). This functional form is able to match the empirical citation lag distribution (which looks log normal in the lag) fairly well and provides easily interpretable estimates of the parameters. Our full model augments this equation to account for EcoPC citation differences in level, decay, and diffusion as well as the post-donation impact:

$$c_{st} = \beta_0(1 + \delta_{eco}D_{eco} + \delta_{after}D_{after})f(t)e^{-\beta_1(1+\beta_{1e}D_{eco})s}(1-e^{-\beta_2(1+\beta_{2e}D_{eco})s}) + \varepsilon_{st} \tag{3}$$

This formulation has the effect of supplying a premium or discount to each of the parameters of the citation lag process for the EcoPC patents. In this case, the unit of observation is the average cites per patents with a given priority year, citation lag, and patent type (EcoPC before and after or control). Even with the data aggregated in this manner, 30 percent of the observations are still zero, so we estimate this model in two ways: (1) via nonlinear least squares on Eq. (3) as in Hall et al. [11]; and (2) using a Poisson model of aggregate cites for a priority year-citation lag-patent type combination with the number of patents in the cell multiplying the right hand side of Eq. (3). That is, in order to use a count data model for the cites, we transform the equation by multiplying both sides by the patent count.[33] The second method may be more appropriate given the large number of zeroes in the data. In all cases, robust standard errors are reported.

The main problem with interpreting the estimates from these kinds of models is the lack of random assignment into "treatment," in this case, the fact that EcoPC patents are likely to be different from the controls before donation as well as after. For example, if more forward citations made it less likely for a patent to be pledged to the EcoPC, the assumption of exogeneity of the right hand side variables would be violated and our estimate of the "pledge effect" biased. Given the relatively limited size of our dataset, especially post-donation, our solution to this problem is to control explicitly for differences in EcoPC citation patterns before donation, which are in fact present.

7.2. Citation data and regressions

The citation data used for the regressions that follow are constructed by collecting all the forward citation records for the EcoPC patents and their controls including cites to their equivalents from Espacenet (as of May 2012). For this part of the analysis, we draw a subsample from our Control 2 sample to match the sample of EcoPCs as closely as possible based on patents' priority year, publication authority, and IPC subclasses. The subsample, therefore, provides a set of control patents that matches the EcoPC patents in terms of the type of protected technology, the age of a patent, and in which jurisdiction/market it protects an invention. The reduced sample size allows us to use the most recent available citation data from Espacenet, which has to be collected individually for each patent record from the Espacenet website.

In the analysis below we use two versions of the citation data thus created: the first is by patent application including the equivalents (238 EcoPC patents and 473 controls) and the second is by the family or set of equivalents (90 EcoPC and 94 controls).[34]

Table 6 shows the number of patents and equivalent groups that receive any citations during the 1989–2011 period as well as the total number of citations received. The table shows that 43 percent of EcoPC patents received any forward citation whereas only 34 percent of the patents in the control sample did. When the unit of analysis is an equivalence group, the result is different, reflecting the fact that the controls have larger families than the EcoPC patents: 78 percent of the EcoPC equivalent groups receive at least one citation whereas the number is 85 percent for the controls. Table 6 also shows average citations for both groups. The figures reveal that the EcoPC patents average fewer citations per equivalence group

---

[33] Ref. [15] measure the cite probability as cites over the number of potential cited patents times the number of potential citing patents. We ignore the second number, as it is the same for all our patents during the citing year, and varies little across citing years (which are in any case already in the model).

[34] We verified that we do not double count citations by checking the equivalent sets of citing patents. For example if patents A and B cite patent C, we verify that A and B are not equivalents. Before doing analysis on the second dataset we collapse the citations within each equivalence group, to avoid double counting them. That is, if the equivalence group contains patent A, cited by patent C, and patent B in the same equivalence group is also cited by patent C, this yields only one citation, from C to the group (A, B).

Table 6
Citation counts for EcoPC patents and controls.

	Total patents		Share with citations		Total citations	
	All patents	Equivalence group	All patents	Equivalence group	All patents	Equivalence group
Eco-patents	238	90	43.3%	77.8%	667	651
Controls	474	94	34.4%	85.1%	1205	1063
	Average citations[a]		Average citations[b]			
Eco-patents	6.48	9.30	2.80	7.23		
Controls	7.39	13.29	2.54	11.31		

Citations are measured as all forward citations in the patent literature between the application date and April/May 2012, adjusted for citations by equivalent patents in other jurisdictions.
 [a] Average over patents with nonzero citations.
 [b] Average over all patents.

and more per patent in each individual jurisdiction. In our estimations, we will focus on equivalent groups rather than individual patents, because these correspond more closely to the concept of an "invention."

Appendix Table A5 shows the distribution of average citations received by citation lag. Citation lags are defined as the difference between the priority dates of the citing and the cited patent. This measure can be interpreted as the age of the patented technology at the point in time it was cited. The first panel of Table A5 shows the distribution of citation lags using a patent as the unit of analysis as opposed to an equivalence group as shown in the second panel of Table A5. The distribution of citation lags ranges from 0 to 20, although this range differs by individual patent according to its priority date.[35] In the first panel, Columns (1)–(3) show the average citations per patent for each citation lag for both EcoPC and control patents. As should be expected, the average citation counts drop considerably as the lag size increases, which means that patents receive on average fewer citations the older they are. The citation lag distribution of the EcoPC sample appears to be slightly skewed to the right relative to the control sample, that is, average citation counts are smaller for low citation lags with the largest differences for citation lags of 1–3 years. Non-parametric (ranksum and Kruskal-Wallis) tests strongly reject the null hypothesis that the EcoPC and control sample citations are drawn from the same distribution. Columns (4) and (5) show the average citations before and after patents have been pledged to the commons, which makes clear that there are few forward citations after patents have been pledged, and also that both older and newer patents are cited.

Using these data, we explored whether the EcoPC patents see an increase in citation rates after they were donated to the commons, using the model in Eqs. (1) and (3). The results are shown in Table 7. The first two columns show estimates obtained for a model with a complete set of priority year and citation lag dummies and the next three columns show the estimates from the Ref. [15] model, obtained using nonlinear least squares and Poisson estimation. All the estimates imply that the EcoPC patents are less cited overall. At the patent level (the first two columns), cites in any given year are about 50 percent lower. Aggregating to priority year-citing year cells (the next three columns), cites are 20 to 30 percent lower, and the effect is much less precisely estimated. Note that the difference between these two sets of estimates is the effective weighting of the observations: when we aggregate to priority year-citing year, we effectively place more weight on those cells that have fewer patents available for citing.

The coefficient of interest is that on the dummy for an EcoPC patent after it has been donated. Here we find uniformly negative, but mostly insignificant values. To summarize, the primary difference between EcoPC patents and the controls is that the former are cited considerably less throughout their life, and perhaps even less after they have been pledged. In addition, the estimates of the Ref. [15] model using the Poisson specification imply the following about the citation distribution of both sets of patents: the knowledge in them "decays" at a rate of about 11 percent per year (β_1) and "diffuses" at a rate which implies peak citation will be reached at a lag of about 6 years (β_2/β_1). The last column shows that the information in EcoPC patents decays insignificantly faster than the controls.[36]

Fig. 4 visualizes the different citation distributions for the control and EcoPC samples along with the fit from column (5) of Table 7. We show the distribution by citing year, in order to see any differences that might occur after donation (which is 2008 for all but 6 of the equivalence groups). The figure shows that the forward citation distributions are quite different for the EcoPC and control patents, with the EcoPC patent citations declining much more before 2008 than those for the controls. For both groups, the average number of cites drops considerably over time with there being very few cites after the establishment of the commons, so we can conclude that the data are insufficient at the present time to answer the question, although as time passes and more citations are received by both sets of patents it will be interesting to look at this question again. However both this figure and the regression results in Table 7 do suggest that these donated patents are somehow different in their class before they are donated: less useful to subsequent inventors and less valuable.

---

[35] The earliest priority date in our sample is 1989 and the latest citation is 2011, implying a maximum citation lag of 22, but in fact we observed no cites at lags 21 and 22.
[36] The model with a separate diffusion parameter for EcoPC patents was not identified in these data.

Table 7
Estimation of citation lag models.

| Model | Semi-parametric | | | | | | Jaffe-Trajtenberg | | | |
| Dependent variable | Cites | | Cites | | Cites/patent | | Cites | | Cites | |
Method	Poisson		Negative binomial		NLLS		Poisson		Poisson	
EcoPC patent	−0.57	(0.12)***	−0.51	(0.11)***	−0.28	(0.12)**	−0.22	(0.12)	−0.22	(0.11)*
EcoPC patent after donation	−0.09	(0.30)	−0.12	(0.27)	−0.28	(0.15)*	−0.58	(0.37)	−0.57	(0.38)
Decay parameter					0.24	(0.06)***	0.11	(0.02)***	0.11	(0.02)***
Diffusion parameter					0.47	(0.34)	0.77	(0.27)***	0.76	(0.32)**
EcoPC decay									0.04	(0.34)
Dispersion parameter			2.50	(0.20)***						
Citation lag dummies	yes		yes		no		no		no	
Priority year dummies	yes		yes		yes		yes		yes	
Observations	2214		2214		380		380		380	
Log likelihood	−2616.1		−2034.4		−379.8		3144.7		3144.8	

Sample: 87 controls and 83 EcoPC patents with priority years between 1992 and 2005 and citing years between 1992 and 2011. The unit of observation in the first two columns is a patent-citing year and in the next two columns a priority year-citing year.
Standard errors are robust to heteroskedasticity.
   *** Significant at the 1% levels.
   ** Significant at the 5% levels.
   * Significant at the 10% levels.
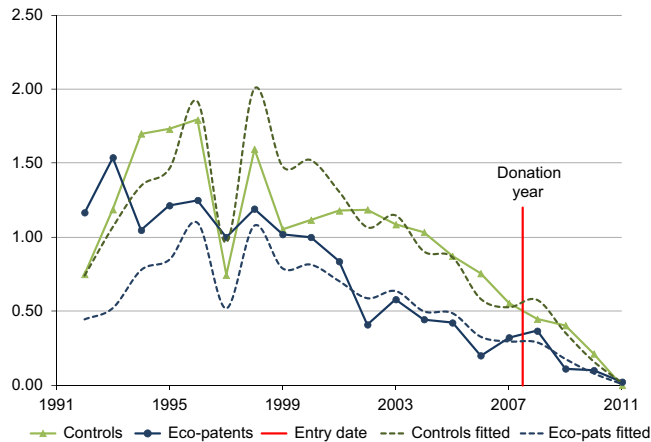

Fig. 4. Cites per patent by citing year (as of May).

8. Conclusions

Recently, mechanisms used by companies to share patents, especially in the form of patent pools, have received increased attention [8], mostly due to an enhanced perception of their use by companies to address problems associated with patent thickets and patents on standard-relevant technologies. In this paper, we provide an assessment of an alternative mechanism to share patents in the area of green technology: the Eco-Patent commons. In contrast to a patent pool, firms that are part of the EcoPC pledge their patents to make them accessible royalty-free to anyone wanting to use the patented invention. In our analysis, we investigate companies' motives to maintain patents in force while making them available royalty free. Because we observe pledged patents before and after they enter the commons, our setting also offers the opportunity to study the effect of a patent commons on the diffusion of patented technologies.

Our analysis of the pledged patents finds that pledged patents indeed protect environmentally friendly technologies in the form of environmental cleanup and clean manufacturing. This finding emerges regardless of whether we compare the EcoPC patents to other patents held by the pledging companies or patents that protect broadly similar technologies.

Regarding firms' motives to pledge these patents, we find that their technology profile is significantly different from the pledging firm's patent portfolio. We also find that firms preponderantly maintain pledged patents in force, which indicates that the commons is not a simple mechanism to reap quick public relations benefits at the moment a patent is pledged. Judging by some indicators of a patent's value, such as the number of inventors, we find that pledged patents are largely indistinguishable from the average patent of a pledging firm's portfolio. Hence, our findings indicate that firms do not simply pledge patents for inventions without any

apparent usefulness to the commons, only to reap good publicity. Rather, the firms grant royalty-free access to potentially useful, although only moderately valuable, green patents that cover technologies they are not able to use.

The same is not true when we compare the EcoPC patents with comparable patents protecting similar technologies. EcoPC patents tend to be more derivative of previous technologies and somewhat narrower than other patents in their class, suggesting that they are not for very radical inventions. In addition, we find that they are less cited than comparable patents *before* they are donated, as well as after. This finding suggests that they are less valuable and that the technology behind these patents may not have much impact on future technologies in this area.

Does the commons succeed in promoting the diffusion of the pledged environmentally friendly technologies? Here, our answer is less conclusive. Our analysis suggests that pledging these patents by making them available to third parties royalty-free, has no discernible impact on the diffusion of the knowledge embedded in the protected technologies to other patenting firms. With regard to the broader discussion of whether patents slow the diffusion of green technology, this could imply that the removal of existing patents might have little effect on the spreading of the previously protected technologies. However, given the short period of time after the patents have been pledged that is available so far, our results are naturally of preliminary nature.

Despite of these findings, patent commons may still represent a mechanism for addressing the diffusion problem inherent in patent protection of technologies with a strong public policy interest, such as environmentally friendly technologies. Our analysis suggests that patent commons, provided they are serious about their objective to enhance diffusion, could be more effective if they promoted the use of pledged technologies more actively, by for example providing concrete suggestions for how these technologies could be employed or used in follow-on inventions. This may ultimately also benefit the companies' original motivation to attract collaborators and encourage exchange by making selected technologies openly available.

In any case, our analysis calls for further work on the effectiveness of patent commons in promoting the diffusion of technologies characterized by a double-externality. It would be interesting to take not only another look at the question of diffusion once the EcoPC has been in place for longer, but also to subject new patent commons in other technology areas, such as WIPO Re:search in pharmaceuticals, to similar analysis.

Appendix A

Table A1
Patents contributed to the commons as a share of firm portfolios and patent classes by application year and priority year.

| | All applications and equivalents by year of application | | | | | Equivalence groups by earliest priority year | | | | |
Year	Eco patents	Patents in the same class	Share (%)	All pats held by eco pats firms	Share (%)	Eco patents	Patents in the same class	Share (%)	All pats held by eco pats firms	Share (%)
1989	3	668	0.449	11,074	0.027	4	861	0.465	11,948	0.033
1990	27	2548	1.060	26,967	0.100	2	220	0.909	15,174	0.013
1991	9	802	1.122	32,517	0.028	1	230	0.435	19,478	0.005
1992	12	2655	0.452	32,398	0.037	5	2048	0.244	20,150	0.025
1993	13	7512	0.173	31,958	0.041	1	1030	0.097	19,673	0.005
1994	11	6592	0.167	31,449	0.035	8	1502	0.533	19,107	0.042
1995	22	8953	0.246	35,258	0.062	7	2693	0.260	21,772	0.032
1996	17	4251	0.400	38,748	0.044	4	2059	0.194	23,638	0.017
1997	13	13,057	0.100	41,607	0.031	9	3750	0.240	25,046	0.036
1998	9	5778	0.156	43,545	0.021	6	1948	0.308	25,313	0.024
1999	11	7462	0.147	44,581	0.025	5	947	0.528	25,840	0.019
2000	7	5376	0.130	48,825	0.014	4	3457	0.116	26,859	0.015
2001	11	19,938	0.055	52,956	0.021	5	8034	0.062	28,481	0.018
2002	9	10,516	0.086	46,082	0.020	5	1081	0.463	25,487	0.020
2003	6	4660	0.129	46,596	0.013	3	1453	0.206	26,579	0.011
2004	12	4049	0.296	46,658	0.026	12	1636	0.733	27,576	0.044
2005	32	5295	0.604	48,804	0.066	9	856	1.051	27,843	0.032
2006	7	2173	0.322	18,355	0.038					
2007	6	888	0.676	2461	0.244					
2008	1	511	0.196	1825	0.055					
2009	0	228	0.000	491	0.000					
Total	**238**	**113,912**	**0.209**	**683,155**	**0.035**	**90**	**33,805**	**0.266**	**389,964**	**0.023**

Table A2
Patent family sizes.

	Number of equivalence groups		Average size of equivalent group		Average family size from docdb		Average family size from inpadoc	
	Eco-patents	Same firms	Eco-patents	Same firms	Eco-patents	Same firms	Eco-patents	Same firms
Bosch	23	30,047	2.26	3.06	2.26	2.88	2.26	3.49
Dow	1	3898	9.00	3.75	8.00	4.37	9.00	12.60
DuPont	11	11,546	3.91	3.53	5.82	3.80	79.09	6.04
FujiXerox	2	36,993	3.00	1.16	3.00	1.15	3.00	1.27
IBM	29	57,014	1.83	1.76	1.97	2.03	3.21	2.53
Mannesmann	1	2467	2.00	2.85	2.00	2.60	2.00	3.18
Nokia	1	12,111	3.00	4.26	3.00	4.24	3.00	4.84
PitneyBowes	2	2018	3.50	2.27	3.50	2.45	3.50	2.93
Ricoh	1	96,016	1.00	1.15	1.00	1.11	1.00	1.44
Sony	4	118,578	1.00	1.55	1.00	1.48	4.50	1.90
Taisei	2	6767	1.00	1.02	1.00	1.02	1.00	1.04
Xerox	13	12,509	4.31	2.28	5.08	2.50	6.92	3.04
All	**90**	**389,964**	**2.64**	**1.75**	**3.02**	**1.77**	**12.81**	**2.30**

Table A3
Patents contributed to the commons by application authority.

	Application authority; equivalents included						Priority appln authority; equivalents and mutliple priorities removed					
Authority	Eco patents	Share (%)	Patents in the same class	Share (%)	All pats held by eco pats firms	Share (%)	Eco patents	Share (%)	Patents in the same class	Share (%)	All pats held by eco pats firms	Share (%)
DE Germany	45	18.9	12,462	10.9	76,719	11.2	24	26.7	3499	10.4	30,885	7.9
JP Japan	34	14.3	20,305	17.8	281,650	41.2	10	11.1	8880	26.3	258,201	66.2
US USPTO	75	31.5	30,742	27.0	141,272	20.7	54	60.0	21,121	62.5	85,087	21.8
Other	84	35.3	50,403	44.2	183,514	26.9	2	2.2	305	0.9	15,791	4.0
Total	**238**		**113,912**		**683,155**		**90**		**33,805**		**389,964**	

Table A4
Patent legal status by firm contributing.

	Uncorrected for equivalents					Priority patents only				
	Number	Granted	Share granted (%)	In force or pending	Share in force (%)	Number	Granted	Share granted (%)	In force or pending	Share in force (%)
Bosch	52	34	65.4	25	48.1	23	18	78.3	11	47.8
Dow	9	6	66.7	4	44.4	1	1	100.0	1	100.0
DuPont	43	23	53.5	18	41.9	11	8	72.7	6	54.5
FujiXerox	6	5	83.3	5	83.3	2	2	100.0	2	100.0
IBM	53	41	77.4	25	47.2	29	27	93.1	24	82.8
Mannesmann	2	1	50.0	0	0.0	1	1	100.0	0	0.0
Nokia	3	2	66.7	2	66.7	1	1	100.0	1	100.0
PitneyBowes	7	6	85.7	5	71.4	2	2	100.0	2	100.0
Ricoh	1	0	0.0	0	0.0	1	0	0.0	0	0.0
Sony	4	4	100.0	4	100.0	4	4	100.0	4	100.0
Taisei	2	2	100.0	2	100.0	2	2	100.0	2	100.0
Xerox	56	49	87.5	33	58.9	13	13	100.0	10	76.9
All	**238**	**173**	**72.7**	**123**	**51.7**	**90**	**79**	**87.8**	**63**	**70.0**

We treat patients with missing legal status as not granted and not in force/pending

Table A5
Average forward citations by citation lag.

Unit of analysis: patent					Unit of analysis: equivalence group				
Lag (1)	Controls (2)	Ecopats (3)	Before (4)	After (5)	Lag (1)	Controls (2)	Ecopats (3)	Before (4)	After (5)
0	0.275	0.109	0.109	0	0	0.968	0.289	0.289	0
1	0.182	0.214	0.214	0	1	0.809	0.567	0.567	0
2	0.370	0.319	0.319	0	2	1.766	0.844	0.844	0
3	0.313	0.332	0.332	0	3	1.436	0.867	0.867	0
4	0.220	0.437	0.429	0.008	4	1.106	1.133	1.122	0.011
5	0.239	0.223	0.210	0.013	5	1.181	0.556	0.511	0.044
6	0.281	0.303	0.294	0.008	6	0.957	0.789	0.767	0.022
7	0.156	0.143	0.139	0.004	7	0.640	0.383	0.370	0.012
8	0.158	0.220	0.220	0	8	0.901	0.565	0.565	0
9	0.137	0.188	0.177	0.011	9	0.627	0.485	0.455	0.030
10	0.092	0.157	0.151	0.006	10	0.418	0.426	0.410	0.016
11	0.096	0.111	0.086	0.025	11	0.500	0.321	0.250	0.071
12	0.083	0.092	0.072	0.020	12	0.375	0.250	0.192	0.058
13	0.032	0.056	0.056	0	13	0.173	0.170	0.170	0
14	0.048	0.046	0.031	0.015	14	0.233	0.146	0.098	0.049
15	0.030	0.059	0.051	0.008	15	0.172	0.219	0.188	0.031
16	0.033	0.018	0.018	0	16	0.192	0.071	0.071	0
17	0.029	0.043	0.011	0.033	17	0.200	0.190	0.048	0.143
18	0.000	0.070	0.070	0	18	0.000	0.308	0.308	0
19	0.000	0.045	0.030	0.015	19	0.000	0.167	0.083	0.083
20	0.026	0.102	0	0.102	20	0.143	0.714	0	0.714
Total	**0.177**	**0.187**	**0.179**	**0.008**	**Total**	**0.818**	**0.531**	**0.507**	**0.024**

Kruskal–Wallis chi-square=12.5 (0.003) for same dist. in cols. 2 & 3.
Ranksum test=-3.54 (0.003) for same distribution in cols. 2 & 3.

Kruskal–Wallis chi-square=9.07 (0.003) for same dist. in cols. 2 & 3.
Ranksum test=3.01 (0.003) for same distribution in cols. 2 & 3.

Appendix B. Supporting information

Supplementary data associated with this article can be found in the online version at ⟨http://dx.doi.org/10.1016/j.jeem. 2012.12.008.⟩

References

[1] O. Alexy, M.G. Reitzig, Gaining it by Giving it Away: Capturing Value in "Mixed" Appropriability Regimes, Available at SSRN, ⟨http://ssrn.com/abstract=1430328⟩, 2010.
[2] A. Arora, A. Gambardella, The market for technology, in: B. Hall, N. Rosenberg (Eds.), Handbook of the Economics of Innovation, Elsevier, 2010.
[3] K.J. Arrow, L. Cohen, P.A. David, et al., A statement on the appropriate role for Research and Development in climate policy, The Economist' Voice 6 (1) (2008).
[4] D. Blumenthal, Stimulating the adoption of health information technology, New England Journal of Medicine 360 (15) (2009) 1477–1479.
[5] D. Bucknell, Eco-patent commons - what's going on? Available at ⟨http://www.thinkipstrategy.com/ipthinktank/272/eco-patent-commons-whats-going-on⟩, 2008.
[6] N. Cronin, Growing the Eco-Patent Commons to Truly Promote Green Innovation, Available at ⟨http://www.greenbiz.com/blog/2008/04/15/growing-eco-patent-commons-truly-promote-green-innovation#ixzz0p97lNnVy⟩, 2008.
[7] P.A. David, C. Huang, L. Soete, A. van Zorn, Toward a Global Science and Technology Policy Agenda for Sustainable Development, Maastricht, Netherlands, UNU-MERIT Policy Brief No. 4, 2009.
[8] US Department of Justice and Federal Trade Commission, Antitrust Enforcement and Intellectual Property Rights: Promoting Innovation and Competition, Washington, DC, Available at ⟨www.usdoj.gov/atr/public/hearings/ip/222655.pdf⟩, 2007.
[9] R. Ghafele, R.D. O'Brian, Open Innovation for Sustainability: Lessons from the GreenXchange Experience, ICTSD Policy Brief No. 13, Available at ⟨http://ictsd.org/downloads/2012/06/open-innovation-for-sustainability-lessons-from-the-greenxchange-experience.pdf⟩, 2012.
[10] B.H. Hall, C. Helmers, The role of patent protection in (clean) technology transfer, Santa Clara High Technology Law Journal 26 (4) (2010) 487–532.
[11] B.H. Hall, A.B. Jaffe, M. TrajtenbergThe NBER Patent Citations Data File: Lessons, Insights, and Methodological Tools, Cambridge, MA, NBER Working Paper no. 8498, 2001.
[12] B.H. Hall, J. Mairesse, L. Turner, Identifying age, cohort, and period effects in scientific research productivity: discussion and illustration using simulated and actual data on French physicists, Economics of Innovation and New Technology 16 (2) (2007) 159–177.
[13] D. Harhoff, F.M. Scherer, K. Vopel, Citations, family size, opposition and the value of patent rights, Research Policy 32 (8) (2003) 1343–1363.
[15] A.B. Jaffe, M. Trajtenberg, International knowledge flows: evidence from patent citations, Economics of Innovation and New Technology 8 (1999) 105–136.
[16] R. Jefferson, Science as social enterprise: the Cambia Bios initiative, Innovations: Technology, Governance, and Globalization 1 (4) (2006) 13–44.
[17] D.K.N. Johnson, D. Popp, Forced out of the Closet: the impact of the American Inventors protection act on the timing of patent disclosure, RAND Journal of Economics 34 (1) (2003) 96–112.
[18] N. Johnstone, I. Hascic, F. Watson, Climate Policy and Technology Innovation and Transfer: An Overview of Recent Results, OECD, Paris, 2010 Report ENV/EPOC/GSP(2020)10.
[19] R. Kemp, Zero emission vehicle mandate in California: misguided policy or example of enlightened leadership?, in: C. Sartorius, S. Zundel (Eds.), Time Strategies, Innovation and Environmental Policy, Edward Elgar Publishing, 2005.
[20] P. Krugman, It's Easy Being Green, 25, New York Times, 2009 ⟨http://www.nytimes.com/2009/09/25/opinion/25krugman.html?_r=1⟩ September 2009.

[21] R. Lampe, P. Moser, Do patent pools encourage innovation? Evidence from the 19th-century sewing machine industry, Journal of Economic History 70 (4) (2010) 898–920.

[22] J.O. Lanjouw, A. Pakes, J. Putnam, How to count patents and value intellectual property: the uses of patent renewal and application data, Journal of Industrial Economics 46 (4) (1998) 405–432.

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

[24] Z. Lei, R. Juneja, B.D. Wright, Patents versus patenting: implications of intellectual property protection for biological research, Nature Biotechnology 27 (1) (2009) 36–40.

[25] C. Martinez, Insight into Different Types of Patent Families, OECD Science, Technology and Industry Working Papers, 2010/2, OECD Publishing, http://dx.doi.org/%2010.1787/5kml97dr6ptl-en, 2010.

[26] D.C. Mowery, Military R&D and innovation, in: B.H. Hall, N. Rosenberg (Eds.), Handbook of the Economics of Innovation, vol. II, Elsevier, Amsterdam, 2010, pp. 1218–1251.

[27] D.C. Mowery, R.R. Nelson, B. Martin, Technology Policy and Global Warming, NESTA Provocation, London, UK10.

[28] W.D. Nordhaus, Economic issues in a designing a global agreement on global warming. Keynote Address at the Climate Change Conference, Copenhagen, Denmark, March 10–12, available at ⟨http://nordhaus.econ.yale.edu/documents/Copenhagen_052909.pdf⟩, 2009.

[29] E. Sapsalis, B. van Pottelsberghe, R. Navon, Academic versus industry patenting: an in-depth analysis of what determines patent value, Research Policy 35 (10) (2006) 1631–1645.

[30] K.R. Srinivas, Sink or swim: eco-patent commons and the transfer of environmentally sustainable technologies, ICTSD News and Analysis 2 (2) (2008). Available at.

[31] M. Van Hoorebeek, W. Onzivu, The eco-patent commons and environmental technology transfer: implications for efforts to tackle climate change, Carbon and Climate Law Review 1 (2010) 13–29.

[32] P.M. Zuniga, D. Guellec, Who Licenses out Patents and Why?: Lessons from a Business Survey, OECD Science, Technology and Industry Working Papers, 2009/5, 2009.