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INNOVATION AND DIFFUSION OF CLEAN/GREEN TECHNOLOGY: CAN PATENT COMMONS HELP?

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ABSTRACT

This paper explores the characteristics of 238 patents on 94 “inventions” contributed by major multinational innovators to the “Eco-Patent Commons”, which provides royalty-free access to third parties to patented climate change related innovations. By comparing the pledged patents to other patents in the same technologies or held by the same multinationals, we 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. This study, therefore, indirectly provides evidence on the role of patents in the development and diffusion of green technologies. More generally, the paper sheds light on the performance of hybrid forms of knowledge management that combine open innovation and patenting.

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1. Introduction

Numerous well-known economists have called for policies to encourage both public and private investment in technologies designed to mitigate climate change (Mowery et al. 2010; David et al. 2009; Krugman 2009; Arrow et al. 2008). As Nordhaus (2009), among others, points out, policy in this area confronts a double externality problem: 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 (2010) 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 and away from intellectual property (IP) protection.

To make this argument more explicit, consider the usual policies designed to close the gap between the private and social returns to an activity.[4] 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 (Mowery, 2010), for corporate R&D via tax credits, and for small and medium-sized enterprises (SMEs) that face credit constraints. Although the second approach has been used much less (and is probably less suitable for R&D activities due to their uncertainty and the difficulty of such micro-management), examples are the mandate of the State of California for sales of electric-powered automobiles (Kemp, 2005) and the U.S. federal government stimulus package, which mandates the diffusion of electronic medical records and their effective use (Blumenthal, 2009).

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 (as in the case of R&D directed toward other national needs), 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

[4] We note in passing that in the case of 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 climate change-related technologies still remains.

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.[5] 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., appear to have recognized the problem with patents in the area of climate change related technologies and as a response, have created 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 which 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. Alternatively, the patents contributed could be those on inventions that need development effort that the firms in question are not willing to undertake. 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 directly climate-change related patents in these firms' total patenting.[7]

[5] For a review of the relevant literature see Hall and Helmers (2010).

[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 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. Yet, we omit HP in our analysis as our core data predates HP's 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 0.12 percent for DuPont to negligible for Ricoh, Sony, Nokia, and FujiXerox.

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) are the patented technologies indeed climate-change related? (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 innovations than otherwise? In particular question (c) is interesting in light of the broader debate on the role of IP in the diffusion of 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 climate change related 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 climate change technology area, insights that may also be useful in other areas where open innovation exists side-by-side with IP protection. In particular, we provide insights into the ability of such hybrid private initiatives to address the double externality problem present in climate change related innovation.

We begin the paper with a discussion of the history and detailed operation of the eco-patent commons. Section 3 describes the data used in our analysis. Section 4 reviews different theoretical motivations for firms to pledge their climate change related patents. 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 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 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, but not specifically towards climate change mitigation.

"Pledge" in this context means making patents available for use by third parties free of charge,[9] although 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 deductable 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.

While a pledge is in principle irrevocable,[10] there is a built-in mechanism to safeguard a pledging firm's business interests which is called "defensive termination". This means that

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[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] 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,

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 "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.[11]

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 member, Hewlett Packard (HP) joined in July 2010, but is excluded from our analysis because our core data are as of April 2010 and thus predate HP's entry into the commons. All patents pledged to the EcoPC are listed in an online data-base (the data base is reproduced in Appendix A1).

The EcoPC is currently the only initiative of this type, although Creative Commons in collaboration with Nike and Best Buy is setting up the Green Xchange initiative. In this new initiative (in contrast to the EcoPC), pledging firms can choose whether to charge a fixed annual 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 Green Xchange 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 climate-change related technologies 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.

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except that it may be deleted for so long as the patent is not enforceable." However, firms obviously 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."

[11] 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 currently vary between EUR 420 and EUR 1,420 depending on how long the application has been pending (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 1,940. 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$ 2,480 and at 11.5 years to US$ 4,110.

Hence, the commons does not ask 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 Januray 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."[12] In a review of the EcoPC initiative, Srinivas (2008) lists a number of 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 (2008) argues in her article in Greenbiz[13] 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.

However, the issue is even more puzzling, because firms actually pay to provide royalty-free access to their patents. As pointed out by Bucknell (2008) in an article for Think IP

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[12] 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.

[13] www.greenbiz.com

Strategy,[14] 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 (2010) 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 to 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 (2010) 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. Alexey and Reitzig (2010), for example, argue that firms may choose to pledge patents to mould the wider appropriability regime that governs their business activity. 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 (Lei et al., 2009), 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" (Jefferson, 2006:

[14] www.thinkipstrategy.com

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 climate change related 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 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.[15] We then used the April 2010 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.[16]
2. Control (1) sample: all patent applications worldwide that were made by the 12 EcoPC firms.
3. Control (2) sample: all patent applications worldwide in the same IPC class as one of the EcoPC patents (which also share the same priority year and 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.

[15] Some of the patent numbers given on WBCSD's website were incorrect. We retrieved the correct numbers either by searching for the patents using the patent titles indicated on the website or by obtaining the information directly from contacting WBCSD. We thank Kana Watanabe at IBM's Corporate Environmental Affairs for assisting in the retrieval of the missing information.

[16] The priority years range from 1989 to 2005, so we restricted the matching samples Control (1) and Control (2) to those years.

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 "invention," preferably the priority application. However a large number of patents are 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. 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.[17]

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.[18] 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 eco-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 implies 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. In the analysis that follows, we choose to solve this problem by occasionally presenting results that use all 238 of the EcoPC patents, but weights the observations by the inverse of the equivalent group or family size, effectively down-

[17] 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.

[18] Note that our definition is essentially the same as the first (equivalents) definition in Martinez (2010). See also Appendix A2 for more details.

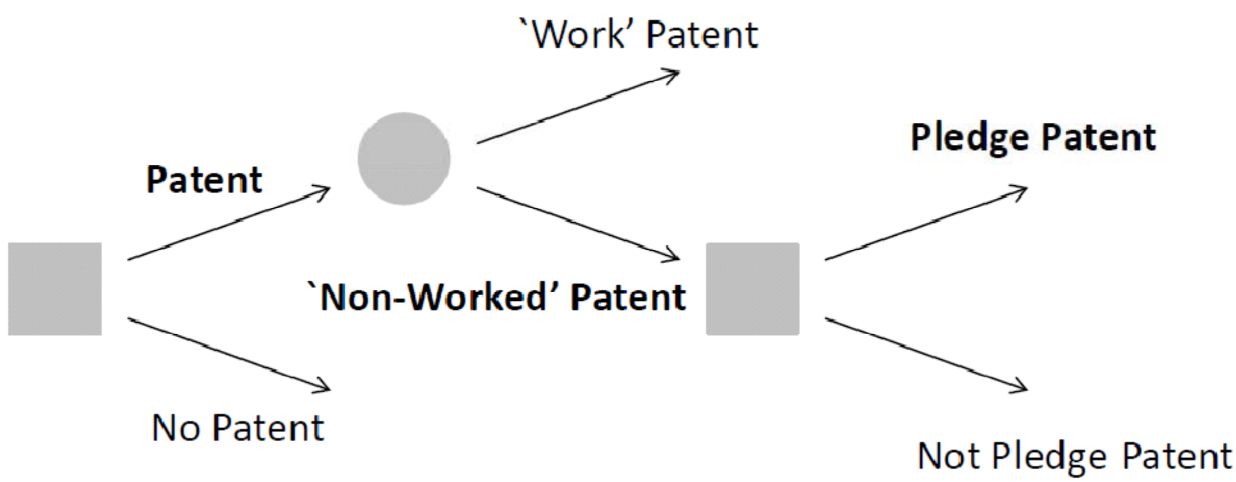
weighting those patents that have many incarnations. We also cluster the standard errors by equivalence group, to allow for within-group correlation of the errors.

Finally, PATSTAT´s April 2010 version does not provide information on the legal status of a patent. It can be inferred from a patent's publication kind code whether it has been granted; however, if a patent has not been granted, it is difficult to infer whether the patent application has been rejected, lapsed, or is simply still pending. Moreover, there is no information on whether renewal fees have been paid. This made it necessary to collect information on patents' legal status manually from EPO's INPADOC, USPTO PAIR, and the various national patent offices (see data appendix A).

4. Which patents do firms pledge?

Figure 1 shows schematically the decision tree of a firm contemplating "working" a patent or abandoning it and its decision to pledge the patent to the EcoPC.

Figure 1: Firm's decision tree



Unfortunately, we only observe some of these decisions. 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.

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 might also expect that these 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, 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 climate-change related? Are the patents that protect these technologies valuable?

Table 1 shows a breakdown of the composition of the different samples. It shows that we have 238 unique patent applications in the EcoPC, which correspond to 94 unique inventions/priorities. The table displays also the corresponding figures for the two control samples. Table 2 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 2 shows that the donated patents are a tiny share of the firms' portfolios (less than 0.1 per cent) and that the majority of the patent families (76 out of 90, or 84 per cent) 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 2 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 two to three 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 3 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 OECD-EPO definition (Johnstone *et al.*, 2010).[19] Second, many of them seem to be related to environmental cleanup or clean manufacturing, and only tangentially to mitigating the effects of global climate change.[20]

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 (Figure 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 (Lanjouw *et al.*, 1998).[21] In Figure 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 in the 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 as of February/March 2011. In Table 4, we look at the legal

[19] 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

[20] 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.'

[21] 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.

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 per cent are pending, and 40 per cent are withdrawn, rejected by the relevant office, lapsed or have expired.[22] Looking at the weighted shares, 64 per cent are in force, about 2 per cent are pending, and 28 per cent 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 suggests that in many cases, at least one of the equivalents is still in force.[23] Additional information is shown in Table A4 in the Appendix, which provides a breakdown of the data by pledging company. Table 5 shows that the firms are more likely to maintain the patents in the US, Germany, or at the EPO, and less likely in other jurisdictions. Table 5 also shows the legal status of a matched control sample of patents in the same technology classes as the EcoPC patents which is discussed in more detail in Section 7. The comparison confirms that USPTO patents are far more likely to be maintained in force than patents from other jurisdictions. It also shows that the share of patents in force is considerably larger for the EcoPC sample, 70 per cent of the priorities pertaining to unique equivalent groups are still in force relative to 38 per cent in the control sample.

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 climate change related, although this is a matter of interpretation as the OECD clean technology definition categorizes only a third of the EcoPC patents as climate change related. 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

[22] 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.

[23] 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.

multivariate probit regressions. The characteristics we look at are the usual bibliometric statistics available in patent data:

- The number of inventors listed on the application, which is related to the amount of resources invested in the invention. 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.
- 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.

We also include a dummy that indicates whether the patent falls in one of the OECD green technology patent classes (Johnstone *et al*. 2010). 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 6 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 forward and backward citations. They are also classified in many fewer IPCs, suggesting that they are narrower than other patents in these classes.

Table 7 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 grouped by equivalence group, and we also present the same regressions weighted by the inverse of the group size for comparison. The results are quite similar. 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. Finally, they have more backward citations which suggests either that they are somewhat derivative, or that they are in a crowded technological field.

Table 8 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. For this probit regression, weighting by the size of the patent family does make a difference. The unweighted results are similar to those for the first control sample: EcoPC patents have more backward citations, fewer IPCs and are more likely to be green. The weighted regression also suggests that they are more valuable than a random patent from the class, with more inventors and a larger family size.

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 relatively valuable, climate change related technologies. The ensuing question is whether pledging these patents 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.

Empirical Approach

There are at least two challenges in assessing the effect of the commons on diffusion and innovation. First, diffusion in terms of application 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. Second, we observe patents for at most three 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 April 2010 citation data with data manually collected from Espacenet as of February 2011.

Mindful of these limitations imposed by data availability, we resort to a difference-in-difference type research design to investigate the question of diffusion. 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. 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 the set of patents in the same technology classes as the EcoPC patents. The unit of observation is therefore cites 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 this variable are quite small (about 80 per cent are zero) so we use Poisson regression with standard errors robust to heteroskedasticity and clustered on the patent for estimation.

The model that we estimate is specified as follows:

$$c_{it} \sim \frac{\lambda_{it}^{c_{it}} e^{\lambda_{it}}}{c_{it}!}$$

$$\lambda_{it} = exp\begin{pmatrix} \alpha_{ip} + [1 - \mathbf{1}(EcoPC_i)] \times \delta(t) \times [1 + \mu \times \mathbf{1}(t \geq \tau_i)] \\ +\mathbf{1}(EcoPC_i) \times \gamma(t) \times [1 + \rho \times \mathbf{1}(t \geq \tau_i)] \end{pmatrix} \qquad t = 1, \dots, 17$$

where c_{it} is the number of citations received by patent i at citation lag t, i.e., the difference between a patent's priority date and the priority date of the citing patent, and α_{ip} are a set of dummies for the patent priority date (between 1989 and 2005).[24] The dummy variable $\mathbf{1}(EcoPC_i)$ is equal to one for EcoPC patents and zero for the control patents. We control for the citation lag distribution for the two samples separately using quadratics in the lag:

$$f(t) = f_0 + f_1 t + f_2 t^2 \qquad f = \ ,$$

The δ and γ functions allow the overall shape of the citation lag distribution to differ between EcoPC patents and the controls. Finally, the dummy variable $\mathbf{1}(t \geq \tau_i)$ is equal to

[24] These dummies are included to allow for the fact that there is lag truncation, so some lags have fewer cites simply because there are fewer patents old enough to have cites with that lag.

one after the establishment of the commons, i.e., when patents are pledged to the EcoPC.[25] The effect of entry into the EcoPC is thus captured by the semi-elasticity ρ, which gives the average per cent change in forward citations following entry in the commons.

So the ρ coefficients inform us about the "pledge effect" in terms of forward citations. The main problem with estimating this model is that the dummy variable $EcoPC_{it}$ is unlikely to be strictly exogenous. 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. In future, we might be able to correct for this problem using the results in the previous section on the characteristics of pledged patents relative to the firms' overall patent portfolios and a control function approach to estimating the Poisson regression.

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 February 2011). 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 codes. The subsample, therefore, provides a set of control patents that is closest to 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. Moreover, the reduced sample size allows us to rely on 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). 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 9 shows the number of patents and equivalent groups that receive any citations during the 1989-2010 period as well as the total number of citations received. The table shows that nearly 35 per cent of EcoPC patents received any forward citation whereas only

[25] Obviously we do not have such a date for the controls, so we have used the date of the establishment of the EcoPC (2008) for them.

25 per cent of the patents in the control sample did. If the unit of analysis is an equivalence group, the pattern changes: the shares of EcoPC and control equivalent groups that receive any citations are nearly the same with 70 and 68 per cent respectively. This change reflects the simple fact that EcoPC patent applications have fewer equivalents and are therefore more likely to be the cited application. Table 9 also shows average citations for both groups. The figures reveal that the EcoPC patents have on average more citations when we look at all patents, but have fewer citations when the unit of analysis is the equivalence group, for the same reason as above.

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 17 where this range differs by patent according to its priority date.

In the first panel, Columns (1)-(3) show the number of average citations 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 less citations the older they are. The citation lag distribution of the EcoPC sample appears to be skewed to the right relative to the control sample, i.e., average citation counts are larger for low citation lags with the largest differences for citation lags of 2-4 years. Non-parametric (ranksum and Kruskal-Wallis) tests also strongly reject the null hypothesis of equal citation lag distributions. 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.

Tables 10a and 10b show the results of the Poisson regressions for citations as a function of the priority year, citation lag and EcoPC patent status (10a is by equivalent group and 10b is by patent). Both reach similar conclusions so we focus on the results in Table 10a for equivalence groups. In all cases the parameter μ, which measures the post-2008 effect for the control sample, is insignificantly different from zero, suggesting that there is no overall change to the cite lag distributions after 2008. Also, for the equivalence group samples but not for the larger samples including equivalents, we are able to accept that the quadratic citation lag distribution is the same for controls and EcoPC patents, so we impose equality in the last two panels of the table, which improves the precision of our estimates. Figure 4 visualizes the different citation distributions for the control and EcoPC samples. The figure shows that the forward citation distributions are indeed very similar for the EcoPC and control patents. For both groups, the average number of cites drops considerably over time with there being very few cites after the establishment of the commons.

In brief, we find that EcoPC patents are significantly less likely to be cited than the controls after they are donated to the commons. The magnitude of the effect is around 40 per cent, with a robust standard error of 16 per cent. The implication is that diffusion in the sense of future inventions building on the donated invention is not increased when a patent is donated to the Eco-Patent Commons. However it is very important to keep in mind that we are only looking at two years worth of citations at the most, and that this kind of knowledge diffusion is only a limited form of diffusion. But the result is suggestive that the inventions protected by donated EcoPC patents may not diffuse more as a result of their royalty-free availability.

8. Conclusions

Are firms dumping valueless patents without any apparent applicability in mitigating climate change into the commons only to reap good publicity? Or is royalty-free access to, in fact, valuable and green patents a promising way to promote the diffusion of climate-change related technologies?

Our answer to the first question is a qualified `No'. Pledged patents appear to be climate-change related, albeit more in form of environmental cleanup or clean manufacturing. Judging by some indicators of a patent's value, such as family size, the EcoPC patents are more valuable than the average patent held by pledging firms and comparable patents protecting similar technologies. However, they 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. Because they are usually distant from the firm's technology (patent) portfolio, one reason for donating them maybe that they are not very valuable to the firm holding them. In spite of this, pledging firms also appear to maintain at least one patent of a patent family in force after it has been pledged by paying the renewal fees.

However, our answer to the second question regarding the commons' potential to enhance diffusion of the protected technologies is even less conclusive. Our analysis suggests that pledging these patents, that is making them available to third parties royalty-free, has no discernible impact on the diffusion of the protected technologies to other patenting firms. If anything, the impact is slightly negative. 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 but invite further scrutiny in the near future.

Figure 2

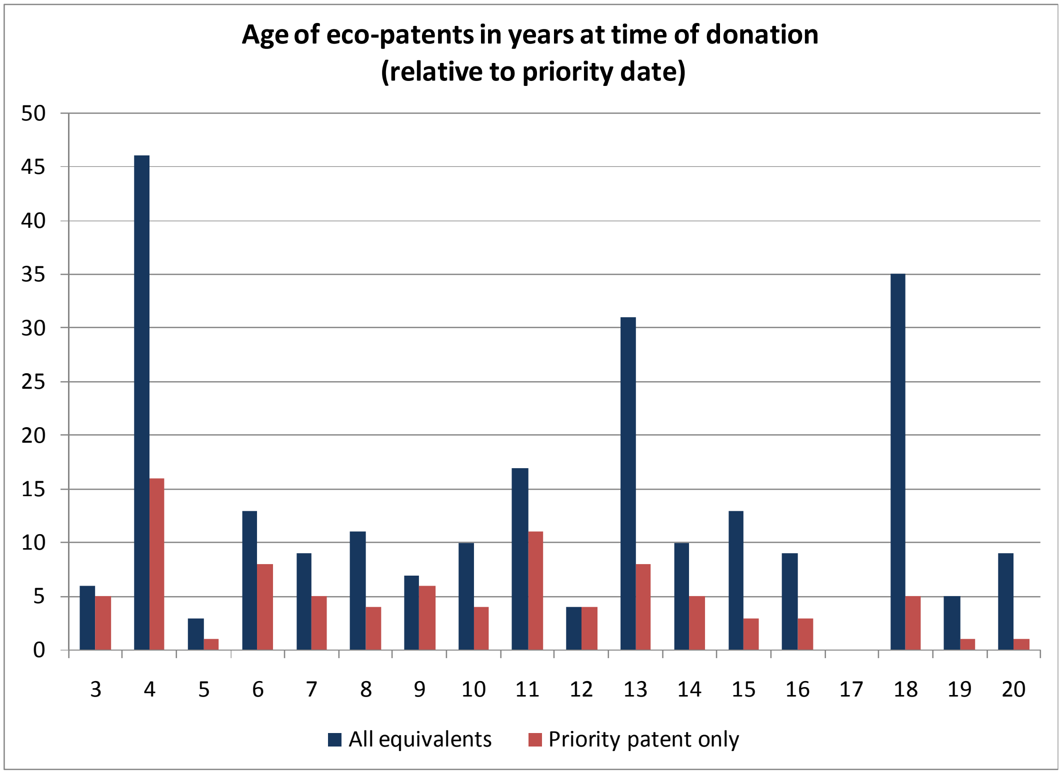


Figure 3

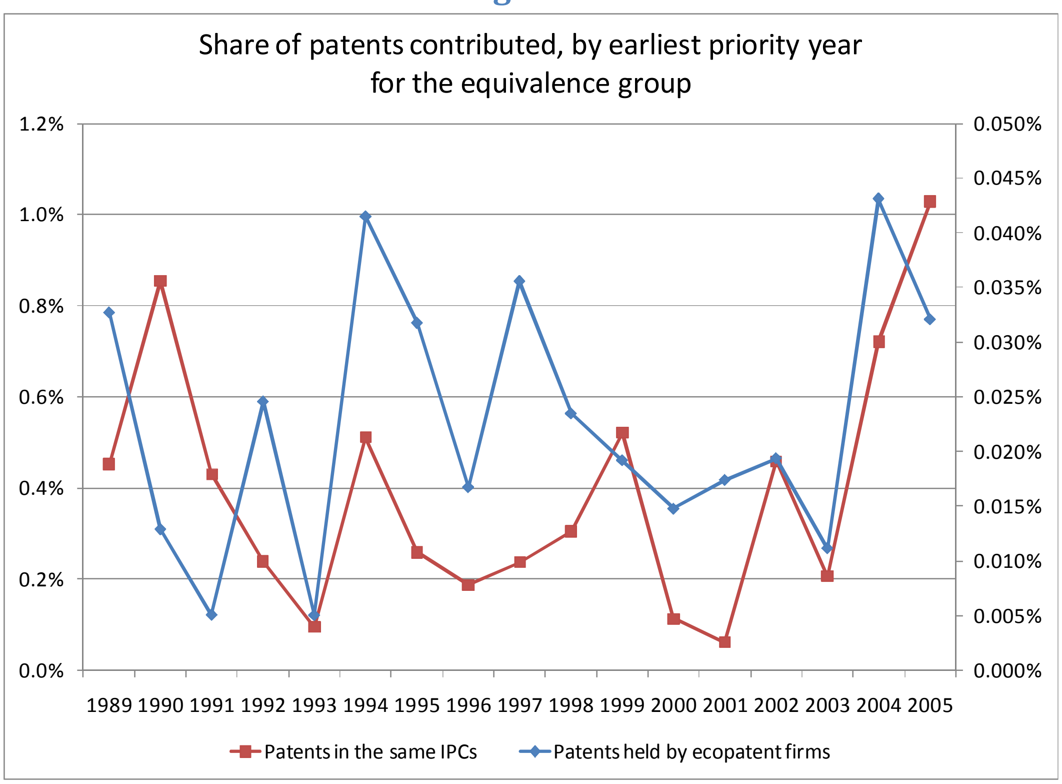
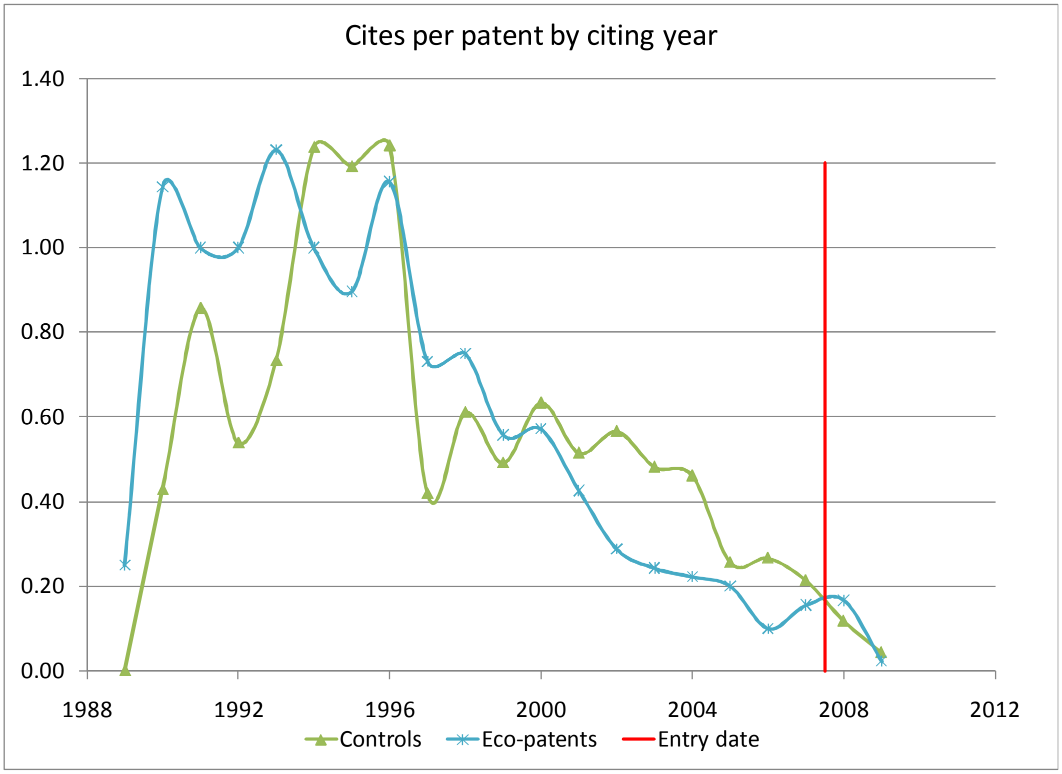


Figure 4


Cites per patent by citing year
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1988
1992
1996
2000
2004
2008
2012
Controls
Eco-patents
Entry date

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10. Data Appendix

A 1: List of Patents contained in Eco Patent Commons

#	Description	Number	Equivalents	Pub Auth	Company	IPC
1	Fuel injection valve for internal combustion engine, with actuator acting via needle carrier on valve needle	EP1084344	DE19915210, JP2002541375, US6575385, WO60232	Germany	Bosch	B05B001-08
2	Fuel injection valve for internal combustion engine, with actuator acting via needle carrier on valve needle	US6575385	DE19915210, EP1084344, JP2002541375, WO60232	Germany	Bosch	B05B001-08
3	Fuel injection valve for internal combustion engine, with actuator acting via needle carrier on valve needle	DE19915210	EP 1084344, JP2002541375, US6575385, WO60232	Germany	Bosch	B05B001-08
4	Fuel injection valve for internal combustion engine, with actuator acting via needle carrier on valve needle	JP2002541375	DE19915210, EP1084344, WO60232, US6575385	Germany	Bosch	B05B001-08
5	Piezoelectric fluid viscosity sensor	EP1393041	DE10123040, *WO02093136*, US2003217589, *JP2004519695*, US6755073	Germany	Bosch	G01N011-16
6	Piezoelectric fluid viscosity sensor	*JP2004519695*	DE10123040, *WO02093136*, EP1393041, US6755073, US2003217589	Germany	Bosch	G01N011-16
7	Piezoelectric fluid viscosity sensor	DE10123040	*WO02093136*, US2003217589 EP1393041, *JP2004519695*, US6755073	Germany	Bosch	G01N011-16
8	Piezoelectric fluid viscosity sensor	*WO02093136*	DE10123040, US2003217589, EP1393041, *JP2004519695*, US6755073	Germany	Bosch	G01N011-16
9	Piezoelectric fluid viscosity sensor	US6755073	DE10123040, *WO02093136*, US2003217589, EP1393041, *JP2004519695*	Germany	Bosch	G01N011-16
10	Climate control system in vehicle with heating and cooling circuits	EP1536961	WO2004024479, DE10240712, *KR2005004862*, *US2006081355*	Europe	Bosch	B60H001-00
11	Climate control system in vehicle with heating and cooling circuits	*DE10240712*	WO2004024479, EP1536961, *KR2005004862*, *US2006081355*	Germany	Bosch	B60H001-00
12	Climate control system in vehicle with heating and cooling circuits	*KR20050048623*	*DE10240712*, EP1536961, WO2004024479, *US2006081355*	Korea	Bosch	B60H001-00
13	Climate control system in vehicle with heating and cooling circuits	*US2006081355*	*DE10240712*, EP1536961, *KR2005004862*, WO2004024479	United States	Bosch	B60H001-00
14	Apparatus for removing contaminants from	EP1070555		Europe	Xerox	B09C

	a contaminated area					
15	Image Forming Device	JP3375028		Japan	Ricoh	G03G
16	Method for recycling optical disks	JP3528898		Japan	Sony	B01D
17	The purification method and purges of shallow water regions	JP3561890		Japan	Taisei	C02F
18	Metallic reflection film recovering device of disklike information recording M medium and its metallic reflection film recording method	JP3704899		Japan	Sony	B01D
19	Method and device for extracting groundwater using high vacuum	JP3095851	EP498676, US5172764	Japan	Xerox	E03F
20	Recycling of disk-like information	JP3855377		Japan	Sony	B08B
21	Flocculating agent and a method for flocculation	JP3876497		Japan	Sony	B01D
22	Method and apparatus for removing contaminant	JP3805414	EP707899, DE69510746	Japan	Xerox	B09C
23	Process for removing contaminants and apparatus therefore	JP3884793	EP747142, DE69629854, DE69612321	Japan	Xerox	B09C
24	Device for extracting contaminated material from discharged stream and method thereof	JP3971480	US6024868, EP792700	Japan	Xerox	B09C
25	The constructing method of the artificial green space of the watersides	JP4015958		Japan	Taisei	E02B
26	Motor cable with ferromagnetic casing	DE4027948	BR 9103806, *JP4234558*, US5197444	Germany	Bosch	F02D033-00
27	Motor cable with ferromagnetic casing	BR9103806	DE4027948, *JP4234558*, US5197444	Brazil	Bosch	F02D033-00
28	Motor cable with ferromagnetic casing	*JP3242425*	DE4027948, BR9103806, US5197444	Japan	Bosch	F02D033-00
29	Motor cable with ferromagnetic casing	US5197444	DE4027948, BR9103806, *JP4234558*	United States	Bosch	F02D033-00
30	Hydraulic drive for sheet metal forming machine	DE4218952		Germany	Bosch	B03B015-18
31	Channel-scanning cordless telephone appts. with microprocessor- begins scanning with particular radio channel assigned to mobile and base stations among number of channels selected by operator.	DE4241838	WO9414272, EP0626118, *JP7503835*, KR100274286	Germany	Bosch	H04B007-26
32	Channel-scanning cordless telephone appts. with microprocessor- begins scanning with particular radio channel assigned to mobile and base stations among number of channels selected by operator.	*EP0626118*	DE4241838, WO9414272, *JP7503835*, KR100274286	Germany	Bosch	H04B007-26
33	Channel-scanning cordless telephone appts. with microprocessor- begins scanning with particular radio channel assigned to mobile and base stations among number of channels selected by operator.	JP3466190	DE4241838, EP0626118, KR100274286	Germany	Bosch	H04B007-26
34	Channel-scanning cordless telephone appts. with microprocessor- begins scanning with particular radio channel assigned to mobile and base stations among number of channels selected by operator.	*KR100274286*	DE4241838, EP0626118, *JP7503835*, WO9414272	Germany	Bosch	H04B007-26
35	Method of anisotropically etching silicon wafers and wafer etching solution	US4941941	KR940008369, JP3126227, JP7013956,	United States	IBM	H01L

			EP421093, DE69022944, CN1052513, CN1024148, AU6314190, AU636388			
36	Water soluble solder flux and paste	US5011546	JP4228289, JP7075788, EP452009	United States	IBM	B23K
37	Process for two phase vacuum extraction of soil contaminants	US5050676	EP420656, JP3202586, DE69029314	United States	Xerox	E21B
38	Tape drive cleaning composition	US5080825	EP432878, MX169000, JP3146596, HK71996, ES2081355, DE69024471, CN1051585, CN1095873, CA2024636, BR9005251	United States	IBM	C11D
39	Process and Apparatus For Groundwater Extraction Using a High Vaccum Process	US5172764	EP498676, MX9102041, JP4 309626, ES2101804, DK498676, DE69219492, CA2053446, BR9200046, AT152645	United States	Xerox	E21B
40	Apparatus for two phase vacuum extraction of soil contaminants	US5197541		United States	Xerox	E21B
41	Catalyst Method for the Dehydrogenation of Hydrocarbons	US5258348	WO9106366 , JP5504907, EP495857, DE69015824, CA2067390, BR9007795, AT116572	United States	Dow	B01J
42	Chemical pre-treatment and biological destruction of propylene carbonate waste streams effluent streams to reduce the biological oxygen demand thereof	US5275734	JP6106183, EP582539	United States	IBM	C02F
43	Solvent stabilization process and method of recovering solvent	US5310428	JP6262003, EP605350	United States	IBM	B08B
44	Supported Catalyst for Dehydrogenation of Hydrocarbons and Method of Preparation of the Catalyst	US5354935		United States	Dow	C07C
45	Process and apparatus for high vaccum groundwater extraction	US5358357	EP622131, EP5464309, DE69428547, DE69407333	United States	Xerox	E03B
46	Packaging system for a component including a compressive and shock-absorbent packing insert	US5439779		United States	IBM	G03C
47	Apparatus and process for treating contaminated soil gases and liquids	US5441365		United States	Xerox	B09B
48	Dual wall multi-extracion tube recovery well	US5464309	EP622131, US5358357, DE69428547, DE69407333	United States	Xerox	E03B
49	Ink-jet printer having variable maintenance algorithm	US5521334	GB2296574, DE19548919, CA2165758	United States	Pitney Bowes	G01G

50	Aqueous soldermask	US5571417		United States	IBM	C02F
51	Method for treating photolithographic developer and stripper waste streams containing resist or solder mask and gamma butyrolactone or benzyl alcohol	US5637442		United States	IBM	B01D
52	Magnetic Refrigerant Compositions and Processes for Making and Using	US5641424	EP753866, MX9602129, JP9033129, ES2162976, DE69616184, BR9603037, AR2429	United States	Xerox	G03G
53	High vacuum extraction of soil contaminants along preferential flow paths	US5655852	US5709505, JP7290038, EP679450, DE69505179	Europe	Xerox	E02D
54	Highly sensitive method for detecting environmental insults	US5683868	WO9413831, KR100262681, JP8504101, IL107815, ES2102811	United States	DuPont	C12Q, C12N
55	Lyophilized bioluminescent bacterial reagent for the detection of toxicants	US5731163	WO9616187, JP10509049, EP793729, DE69527850, CA2200702, AT222605	United States	DuPont	C12Q, C12N
56	Method for treating photolithographic developer and stripper waste streams containing resist or solder mask and gamma butyrolactone or benzyl alcohol	US5824157		United States	IBM	B05C
57	Fluid jet impregnation	US5863332		United States	IBM	B05C
58	Vacuum application method and apparatus for removing liquid contaminants from groundwater	US5979554	EP911071, JP11207101, DE69835928	United States	Xerox	E21B
59	Fluid jet impregnating and coating device with thickness control capability	US5994597		United States	IBM	C07C
60	Process for recovering high boiling solvents from a photolithographic waste stream comprising less than 10 percent by weight monomeric units	US6021402		United States	IBM	G06F
61	Air flow control circuit for sustaining vacuum conditions in a contaminant extraction well	US6024868	JP9225448, EP792700, DE69714101, BR9701080	United States	Xerox	C02F
62	Multiple overload protection for electronic scales	US6045206	EP934828, CA2261284	United States	Pitney Bowes	G07B
63	Automatic aspirator air control system	US6048134	EP928642, JP11253785, DE69909534	United States	Xerox	B09B
64	Risk management system for electric utilities	US6127097		United States	IBM	G03F
65	Photoresist develop and strip solvent compositions and method for their use	US6178973		United States	IBM	B08B
66	Method and apparatus for ozone generation and surface treatment	US6187965	KR20000035014	United States	IBM	C07C
67	Process for recovering high boiling solvents from a photolithographic waste stream comprising at least 10 percent by weight of monomeric units	US6197267		United States	IBM	F01N
68	Catalytic reactor	US6210862	US2002177072,	United	IBM	G03F

			US6576382	States		
69	Composition for photoimaging	US6221269		United States	IBM	C03C
70	Method of etching molybdenum metal from substrates	US6294028		United States	IBM	C23G
71	Mercury process gold ballbond removal apparatus	US6419566		United States	IBM	B24C
72	System for cleaning contamination from magnetic recording media rows	US6426007		United States	IBM	C02F
73	Removal of soluble metals in waste water from aqueous cleaning and etching processes	US6440639		United States	IBM	G03C
74	Method for deterring drive voltage of fuel injection valve piezoelectric actuator	US6499464	DE10032022, GB2364400, JP2002070683, FR2811016, GB2364400	United States	Bosch	F02D041-20
75	Method for deterring drive voltage of fuel injection valve piezoelectric actuator	DE10032022	GB2364400, JP2002070683, US6499464, FR2811016, US2002046734	Germany	Bosch	F02D041-20
76	Method for deterring drive voltage of fuel injection valve piezoelectric actuator	GB2364400	DE10032022, JP2002070683, US6499464, FR2811016, US2002046734	UK	Bosch	F02D041-20
77	Method for deterring drive voltage of fuel injection valve piezoelectric actuator	JP2002070683	DE10032022, GB2364400, US6499464, FR2811016, US2002046734	Japan	Bosch	F02D041-20
78	Method for deterring drive voltage of fuel injection valve piezoelectric actuator	FR2811016	DE10032022, GB2364400, JP2002070683, US6499464, US2002046734	France	Bosch	F02D041-20
79	High-aspect ratio resist development using safe-solvent mixtures of alcohol and water	US6503874		United States	IBM	B08B
80	Cleaning method to remove flux residue in electronic assembly	US6576382	US6210862	United States	IBM	G03F
81	Composition for photoimaging	US6585906		United States	IBM	B44C
82	Cellular Arrays for the Identificaiton of Altered Gene Expression	US6716582	US2004146922, US2004142373	United States	DuPont	C12Q
83	Method for recycling a disk having a layered structure on a glass substrate	US6800141		United States	IBM	B08B
84	Semi-aqueous solvent based method of cleaning rosin flux residue	US6891640	JP2003136811	United States	IBM	G06K
85	Apparatus and method for reusing printed media for printing information	US6997323		United States	IBM	B65D
86	Method to accelerate biodegration of aliphatic-aromatic copolyesters by enzymatic treatment	US7053130		United States	DuPont	C08G, C08J
87	Systems and methods for recycling of cell phones at the end of life	US7251458	EP1480419, AT402558	United States	Nokia	H04B
88	1,1,1,2,2,4,5,5,5- Nonafluoro-4-(Trifluoromethyl)-3-Pentanone Refrigerant Compositions Comprising a Hydrofluorocarbon and Uses Thereof	US7314576	US2005263737, US7153448	United States	DuPont	C09K
89	1,1,1,2,2,4,5,5,5- Nonafluoro-4-(Trifluoromethyl)-3-Pentanone Refrigerant Compositions Comprising a Hydrocarbon and Uses Thereof	US7332103	US2005263738, US7094356	United States	DuPont	C09K
90	1,1,1,2,2,4,5,5,5- Nonafluoro-4-	US7338616	US2005263735,	United	DuPont	C09K

	(Trifluoromethyl)-3-Pentanone Refrigerant Compositions Comprising a Hydrofluorocarbon and Uses Thereof		US7074343	States		
91	1,1,1,2,2,3,3,4,4- Nonafluoro-4-Methoxybutane Refrigerant Compositions Comprising Functionalized Organic Compounds and Uses Thereof	US7351351	US2005285076, WO2006012096, US2008169446, RU2007103192, NO20070398, MXPA6014218, KR2007003908, JP2008505212, EP1771526, CA2565349, BRPI0512456, AU2005267439	United States	DuPont	C09K
92	1,1,1,2,2,3,3,4,4- Nonafluoro-4-Methoxybutane Refrigerant Compositions Comprising a Hydrofluorocarbon and Uses Thereof	US7354529	US2005151112	United States	DuPont	C09K
93	Protecting exhaust gas conducting parts of IC engine	DE10211152		Germany	Bosch	F02B005-02
94	Electric current generator for motor vehicle	DE10214614		Germany	Bosch	H02K007-116
95	Mapping route in navigation system	DE102004022265	EP1593937	Germany	Bosch	G01C02-34
96	Production of a filter element of a particle filter for an internal engine	DE102004028887	WO2005123219	Germany	Bosch	B01D039-00
97	Production of region of filter structure for a particle filter	DE102004035310	WO2006008209	Germany	Bosch	B01D039-20
98	Device for fuel-saving through electrical energy management controls load(s)	DE102004038185		Germany	Bosch	H02J001-00
99	Filter for removing particles from a a gas stream	DE102004044338	WO2006027289	Germany	Bosch	B01D046-24
100	Equalizing process for Lambda values of engine cylinders	DE102005005765		Germany	Bosch	F02D041-14
101	Varnishing unit, especially for valve housing	DE102005006457	WO2006122587	Germany	Bosch	B05B005-08
102	Filter device, for an exhaust system of an internal combustion engine	DE102005006502		Germany	Bosch	F01N003-021
103	Exhaust gas sooty particles filter for diesel internal combustion engines	*DE102005035593*		Germany	Bosch	B01D046-02
104	Device for energy supply to hybrid motor vehicle	DE102005042654	WO2007028755	Germany	Bosch	B60K006-04
105	Particle filter for e.g. diesel engine	DE102005046051		Germany	Bosch	F01N003-28
106	Illuminated emergency exit sign, for a building	DE202004012616		Germany	Bosch	G09F013-18
107	Motor cable with ferromagnetic casing	DE19963301	*US2001020542*	Germany	Bosch	H01B005-18
108	Motor cable with ferromagnetic casing	*US2001020542*	DE19963301	Germany	Bosch	H01B005-18
109	Particle filter bag for use in internal combustion engine	*DE102005042207*		Germany	Bosch	F01N003-022
110	Hydrofluorocarbon Refrigerant Compositions and Uses Thereof	US7413675	US2005285074, WO2006012095, NO20070399, RU2007103169	United States	DuPont	C09K
111	1,1,1,2,2,4,5,5,5-Nonafluoro-4-(Trifluoromethyl)-3-Pentanone Refrigerant Compositions Comprising a Hydrofluorocarbon and Uses Thereof	US7479239	US2008061265	United States	DuPont	C09K
112	Wastewater Treatment Process	JP4140449	JP2004351379	Japan	Fuji-Xerox	C02F
113	Wastewater Treatment Process	US7468137	US2006283806, EP1734009, KR2006013244, JP2006346610, CN1880240, CN100484887	United States	Fuji-Xerox	C02F
114	Improved process and apparatus for high vacuum groundwater extraction	EP0622131	US5464309, US5358357,	Europe	Xerox	B09C

			DE69428547, DE69407333			
115	Vertical isolation system for two-phase vaccum extraction of soil and groundwater contaminants	*US5709505*	US5655852, JP7290038, EP679450, DE69505179	United States	Xerox	E21B
116	Vertical isolation system for two-phase vacuum extraction of soil and groundwater contaminants	EP0747142	JP8332476, DE69629854, DE69612321	Europe	Xerox	B09C
117	Improved apparatus for high vacuum groundwater extraction	EP0775535		Europe	Xerox	B09C
118	Apparatus and methods for removing contaminants	*EP0792700*	US6024868, JP9225448, DE69714101	Europe	Xerox	B09C
119	Improved process and apparatus for groundwater extraction using a high vacuum process	*EP0498676*	US5172764, MX9102041, JP4309626	Europe	Xerox	E03F
120	Apparatus for removing liquid contaminants	EP0911071	US5979554, JP11207101, DE69835928	Europe	Xerox	B01D
121	Producing particulates filter	DE102005032842		Germany	Bosch	B22F003-105

Notes:

1) Corrected numbers in italic red.

2) Underlined numbers in green added by the authors to list available on EcoPC website.

3) Data on equivalents extracted from Espacenet (http://ep.espacenet.com)

A 2: Construction of core dataset

The patent numbers given in Column 3 of Table A 1 are used to extract additional information on these Eco-Patent Commons (EcoPC) patents from the European Patent Office (EPO) Worldwide Patent Statistical Database (PATSTAT) version April 2010. PATSTAT combines patent information from several sources: DocDB (the EPO master bibliographic database containing abstracts and citations), PRS (the patent register for legal data), EPASYS (the database for EP patent grant procedure data), and the EPO patent register as well as the USPTO patent database for names and addresses of applicants and inventors.

In a first step, we extract from Espacenet all equivalents of the patent numbers given in Column 3 of Table A 1. In a second step, we retrieve from PATSTAT all patents with the same publication number as an EcoPC patent. In a third step, we also match the publication authority and keep the record in PATSTAT that is at the most advanced stage of the grant process as indicated by its publication kind. For example in the case of the US, if both A1 (first published patent application) and B1 (granted patent as first publication) documents are available,[26] we focus on the B1 document.

[26] These definitions apply since 2001.

We then add a range of information covering the application, publication, IPC codes, applicant and inventor, priorities, and patent families as defined in DOCDB and INPADOC (for more information on patent families see Martinez, 2010). We also create a variable that marks patents that belong to the same set of equivalents. Our algorithm assigns patents into the same equivalent group if patents share exactly the same priority documents.[27] We also include backward and forward citations as well as citations of non-patent documents. Since forward citations are truncated by the PATSTAT version that we use, we collect in addition the most recent forward citations from Espacenet.[28] We face the same issue in determining whether an EcoPC has been granted. Thus, we also collect the most recent available publication kind from Espacenet in order to create an indicator variable showing whether a patent has been granted. In addition, we collect manually information on the legal status (as of February/March 2011) of EcoPC patents from a various sources, including INPADOC, IPDL, KIPRIS, DPinfo, INPI, and USPTO PAIR.[29]

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[27] We also assign patents to the same equivalent set that display the following patterns:

1)

Application_id	Priorityid_1	Priorityid_2
A	B	
B	A	
C	A	B

2)

Application_id	Priorityid_1	Priorityid_2	Priorityid_3
A	B	C	
D	A	B	C

[28] http://ep.espacenet.com

[29] The information for the core dataset as well as the matched Control 2 sample was retrieved from the following websites (with the corresponding country code):

AR: http://www.inpi.gov.ar/conweb/ParametrosPatentes.asp
AU: http://www.ipaustralia.gov.au/auspat/index.htm
BR: http://pesquisa.inpi.gov.br/MarcaPatente/jsp/servimg/servimg.jsp?BasePesquisa=Patentes
CA: http://brevets-patents.ic.gc.ca
CN: http://english.cnipr.com/enpatv/search/tableSearch.do?method=showTable
CZ: http://www.upv.cz/en/provided-services/online-databases/patent-and-utility-model-databases/national-database.html
DE: https://dpinfo.dpma.de
DK: http://onlineweb.dkpto.dk/pvsonline/Patent
EP, EA, AT, IL, TW, WO: http://ep.espacenet.com
ES: http://sitadex.oepm.es/ServCons/SitJurExpGra
FI: http://patent.prh.fi/patinfo/default2.asp
FR: http://regbrvfr.inpi.fr/portal
GB: http://www.ipo.gov.uk/types/patent/p-os/p-find/p-find-number.htm
HK: http://ipsearch.ipd.gov.hk/patent/index.html
ID: http://ipdl.dgip.go.id/ipdl_ext/TopjaxServletH2H
JP: http://www.ipdl.inpit.go.jp
KR: http://patent2.kipris.or.kr/pateng
MX: http://www.pymetec.gob.mx/buscador/avanzada.php
NO: https://dbsearch2.patentstyret.no
NZ: http://www.iponz.govt.nz/cms/banner_template/IPPATENT
PH: http://patents.ipophil.gov.ph/PatSearch2
PL: http://www.uprp.pl/patentwebaccess/index.aspx
PT: http://servicosonline.inpi.pt/pesquisas/main/patentes.jsp?lang=PT
RU: http://ru.espacenet.com/search97cgi/s97_cgi.exe?Action=FormGen&Template=ru/ru/number.hts

A 3: Construction of comparison sample 1 (patents from same applicant)

We use a list of standardized firm names of companies that have pledged patents to the EcoPC to extract all other patents assigned to these firms from PATSTAT. Notably, we first extracted all assignee names available in PATSTAT and then filtered the nearly 37 million entries for the names of our EcoPC firms. This approach ensured that we caught all patents held by our firms regardless of the different ways in which firms names are entered into PATSTAT – we found that for some of our firms, PATSTAT included several hundred different ways in which the names are entered. We extract the same range of information on these control patents as for the core EcoPC patents except for their legal status (see description in A 2).

A 4: Construction of comparison sample 2 (patents with same (i) priority authority, (ii) priority year, and (iii) IPC)

The second control group is selected based on a unique list of (i) priority authority, (ii) priority year, and (iii) IPC of the EcoPC patents. This list is used to extract from PATSTAT all other patents (and their equivalents) which share features (i)-(iii) with the EcoPC patents. In a second step, we eliminated manually all individual and non-profit assignees from the control sample. We extract the same range of information on these control patents as for the core EcoPC patents including their legal status (see description in A 2).

TR: http://online.tpe.gov.tr/EPATENT/servlet/EPreSearchRequestManager
SG: http://www.surfip.gov.sg/_patent-f.htm
US: http://portal.uspto.gov/external/portal/pair
ZA: http://patentsearch.cipro.gov.za/patents/patentsearch.aspx

Table 1: Data on priorities

	EcoPC patents	*Control1*	*EcoPC share*	*Control2*	*EcoPC share*
N of unique applications	238	684,718	0.035%	114,172	0.21%
N of unique priorities	94	398,433	0.024%	40,708	0.23%
N of applications with multiple priors	36	41,991	0.086%	25,621	0.14%
N of priors with multiple applns	47	111,173	0.042%	21,316	0.22%
N of unique appln-prior combinations	280	747,119	0.037%	184,526	0.15%
N of equivalent groups	90	394,167	0.023%	34,315	0.26%
Average family size (apps per equiv group)	2.64	1.74		3.33	

Table 2: 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	40,991	0.105%	11	11,949	0.092%	3.91	3.43
IBM	Jan-08	53	100,112	0.053%	29	57,199	0.051%	1.83	1.75
Mannesmann	Jan-08	2	7,068	0.028%	1	2,602	0.038%	2.00	2.72
Nokia	Jan-08	3	52,303	0.006%	1	12,557	0.008%	3.00	4.17
PitneyBowes	Jan-08	7	4,594	0.152%	2	2036	0.098%	3.50	2.26
Sony	Jan-08	4	184,178	0.002%	4	119,207	0.003%	1.00	1.55
Bosch	Sep-08	52	92,121	0.056%	23	30,936	0.074%	2.26	2.98
Xerox	Sep-08	56	28,494	0.197%	13	12,567	0.103%	4.31	2.27
Ricoh	Mar-09	1	110,019	0.001%	1	97,139	0.001%	1.00	1.13
Taisei	Mar-09	2	6,923	0.029%	2	6,770	0.030%	1.00	1.02
Dow	Oct-09	9	14,908	0.060%	1	4,096	0.024%	9.00	3.64
FujiXerox	Oct-09	6	43,007	0.014%	2	37,109	0.005%	3.00	1.16
Total		**238**	**684,718**	**0.035%**	**90**	**394,167**	**0.023%**	**2.64**	**1.74**

Table 3
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 & 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**

Table 4: Average age in years of patent by legal status*

	Number	Share	Mean	Median	Q1	Q3
			Unweighted			
In force	117	49.2%	10.5	10.9	6.2	13.6
Nonpayment of fees	37	15.5%	12.4	13.9	8.1	17.7
Expired	19	8.0%	17.7	18.3	17.7	18.3
Withdrawn	23	9.7%	8.3	10.9	4.3	10.9
Rejected	16	6.7%	8.4	6.2	4.4	8.5
Unexamined/Pending	4	1.7%	4.2	4.2	4.1	4.3
Published in National Office	2	0.8%	4.3	4.3	4.3	4.3
NA	20	8.4%	14.3	15.7	12.8	18.2
All	**238**		**11.2**	**11.0**	**6.1**	**15.8**
			Weighted by inverse of family size			
In force	57.58	64.0%	9.2	9.4	5.8	12.2
Nonpayment of fees	10.54	11.7%	10.6	10.7	4.3	15.8
Expired	3.48	3.9%	16.8	18.1	15.8	18.3
Withdrawn	7.12	7.9%	7.8	6.6	4.7	9.9
Rejected	4.14	4.6%	7.9	6.3	4.4	8.5
Unexamined/Pending	1.59	1.8%	4.2	4.2	4.1	4.3
Published in National Office	0.34	0.4%	4.3	4.3	4.3	4.3
NA	5.21	5.8%	13.9	13.5	12.4	17.7
All	**90**		**9.6**	**9.4**	**5.7**	**13.2**

*Age is measured on April 1, 2010, as years since the application date of the patent.
Legal status as of February/March 2011.

Table 5: Legal status by jurisdiction

Uncorrected for equivalents

		EcoPC Patents			Patents in same classes as EcoPC patents		
	Application authority	Patent not in force	Patent in force	Share in force	Patent not in force	Patent in force	Share in force
US	US	20	55	73.3%	30	83	73.5%
DE	Germany	22	23	51.1%	40	24	37.5%
EP	EPO	18	16	47.1%	42	19	31.1%
JP	Japan	19	15	44.1%	46	15	24.6%
	Other	40	10	20.0%	107	67	38.5%
	Total	**119**	**119**	**50.0%**	**265**	**208**	**44.0%**

Unique equivalent groups

		EcoPC Patents			Patents in same classes as EcoPC patents		
	Application authority	Patent not in force	Patent in force	Share in force	Patent not in force	Patent in force	Share in force
US	US	9	42	82.4%	9	24	72.7%
DE	Germany	13	11	45.8%	17	4	19.0%
EP	EPO	0	1	100.0%	7	0	0.0%
JP	Japan	4	9	69.2%	16	5	23.8%
	Other	1	0	0.0%	9	3	25.0%
	Total	**27**	**63**	**70.0%**	**58**	**36**	**38.3%**

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

Table 6: Statistics on regression variables

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

	*Mean**		*Std. Dev.**		*T-test*	*z-test*	*Minimum*		*Maximum*	
Variable	*Ecopatents*	*Other*	*Ecopatents*	*Other*	*Difference*	*Ranksum*	*Ecopatents*	*Other*	*Ecopatents*	*Other*
Number of inventors	1.957	1.520	0.599	0.583	**4.6**	**4.7**	0	0	8	28
Family size	3.926	2.509	0.595	0.604	**8.2**	**8.8**	1	1	13	69
Forward citations to 2010	0.824	0.721	0.969	0.909	1.5	0.7	0	0	67	642
Backward citations	1.581	0.827	1.103	0.999	**6.4**	**5.8**	0	0	48	157
Non-patent references	0.298	0.200	0.569	0.489	**7.6**	**2.5**	0	0	25	116
Number of IPCs	4.270	3.655	0.511	0.544	**3.3**	**3.6**	1	1	15	131
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**	**-13.0**	0.000	0.000	0.331	0.791
D (inventors missing)	0.139	0.170	0.346	0.375	-1.0	-1.3	0	0	1	1

*Geometric mean for the first 6 variables; standard deviation of the log of the variable.

Based on 238 observations for EcoPC patents and 684,634 for other patents owned by the same firms.

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

	*Mean**		*Std. Dev.**		*T-test*	*z-test*	*Minimum*		*Maximum*	
Variable	*Ecopatents*	*Same classes*	*Ecopatents*	*Same classes*	*Difference*	*Ranksum*	*Eco patents*	*Same classes*	*Eco patents*	*Same classes*
Number of inventors	1.957	1.991	0.599	0.635	-0.3	0.0	0	0	8	37
Family size	3.926	5.281	0.595	0.786	**-5.4**	**-5.1**	1	1	13	101
Forward citations to 2010	0.824	0.502	0.969	0.894	**5.6**	**4.7**	0	0	67	589
Backward citations	1.581	0.719	1.103	1.047	**7.8**	**7.7**	0	0	48	152
Non-patent references	0.298	0.342	0.569	0.792	-2.6	-1.4	0	0	25	163
Number of IPCs	4.270	7.457	0.511	0.727	**-11.9**	**-10.5**	1	1	14	217
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

*Geometric mean for the first 6 variables; standard deviation of the log of the variable.

Based on 238 observations for EcoPC patents and 114,172 observations for others in the same classes.

Table 7: Determinants of the probability that a firm contributes a patent to the EcoPC

684,956 observations (238 = 1) , priority year 1989-2005

	Coefficient	*Std. error*		*Coefficient*	*Std. error*		*Coefficient*	*Std. error*	
Unweighted									
Log number of inventors	-0.040	0.100		-0.006	0.094		-0.012	0.092	
Log family size	0.189	0.089	**	0.166	0.085	*	0.155	0.085	*
Log forward citations to 2010	-0.044	0.029		-0.037	0.028		-0.042	0.028	
Log backward citations	0.091	0.032	***	0.076	0.030	**	0.082	0.030	***
Log non-patent references	-0.014	0.039		-0.010	0.038		-0.004	0.039	
Log number of IPCs	-0.162	0.095	*	-0.121	0.092		-0.186	0.092	**
Similarity measure	-2.189	0.633	***	-2.702	0.723	***			
Dummy for OECD greentech class	0.975	0.102	***						
Dummy for missing # inventors	-0.196	0.186		-0.145	0.175		-0.159	0.172	
Priority year dummies	yes			yes			yes		
IPC (1) dummies	yes			yes			yes		
Firm dummies	yes			yes			yes		
Pseudo R-squared	0.247			0.198			0.178		
Log likelihood	-1606.51			-1711.33			-1752.96		
Probit, weighted by the inverse of the equivalent group size									
Log number of inventors	-0.002	0.077		0.038	0.072		0.038	0.070	
Log family size	0.193	0.076	**	0.161	0.072	**	0.144	0.072	**
Log forward citations to 2010	-0.043	0.032		-0.037	0.031		-0.040	0.030	
Log backward citations	0.118	0.032	***	0.099	0.030	***	0.105	0.029	***
Log non-patent references	0.018	0.051		0.019	0.051		0.016	0.050	
Log number of IPCs	-0.154	0.067	**	-0.118	0.064	*	-0.175	0.064	***
Similarity measure	-2.440	0.561	***	-2.871	0.617	***			
Dummy for OECD greentech class	1.034	0.093	***						
Dummy for missing # inventors	-0.605	0.173	***	-0.539	0.169	***	-0.542	0.165	***
Priority year dummies	yes			yes			yes		
IPC (1) dummies	yes			yes			yes		
Firm dummies	yes			yes			yes		
Pseudo R-squared	0.279			0.220			0.198		
Log likelihood	-609.29			-658.82			-677.93		

[illegible]

Table 8: Determinants of the probability that a patent in an EcoPC patent class is contributed to the commons						
114,172 observations (238 = 1) , priority year 1989-2005						
	Coefficient	*Std. error*		*Coefficient*	*Std. error*	
Unweighted						
Log number of inventors	0.089	0.109		0.084	0.106	
Log family size	0.024	0.073		0.006	0.073	
Log forward citations to 2008	-0.045	0.033		-0.048	0.032	
Log backward citations	0.133	0.028	***	0.133	0.027	***
Log non-patent references	-0.065	0.035	*	-0.071	0.035	**
Log number of IPCs	-0.485	0.097	***	-0.495	0.095	***
Dummy for OECD greentech class	0.486	0.124	***			
Dummy for missing # inventors	0.208	0.155		0.206	0.152	
Priority year dummies	yes			yes		
IPC (1) dummies	yes			yes		
Pseudo R-squared	0.135			0.120		
Log likelihood	-1476.65			-1502.33		
Probit, weighted by the inverse of the equivalent group size						
Log number of inventors	0.186	0.084	**	0.180	0.083	**
Log family size	0.150	0.060	**	0.115	0.060	*
Log forward citations to 2008	-0.048	0.035		-0.054	0.033	
Log backward citations	0.144	0.032	***	0.141	0.031	***
Log non-patent references	-0.076	0.046		-0.088	0.046	*
Log number of IPCs	-0.461	0.069	***	-0.462	0.067	***
Dummy for OECD greentech class	0.500	0.114	***			
Dummy for missing # inventors	0.245	0.140	*	0.249	0.139	*
Priority year dummies	yes			yes		
IPC (1) dummies	yes			yes		
Pseudo R-squared	0.097			0.081		
Log likelihood	-564.18			-574.87		
Heteroskedastic standard errors, clustered by equivalence group.						

Significant at the 1% (***), 5% (**) and 10% (*) levels.

Table 9: Citation counts for EcoPC patents and controls

	all patents	*equivalence group*	*all patents*	*equivalence group*	*all patents*	*equivalence group*
	Total patents		*Share with citations*		*Total citations*	
Eco-patents	238	90	34.5%	67.8%	411	401
Controls	473	94	25.2%	70.2%	520	498
	*Average citations**		*Average citations***			
Eco-patents	5.01	6.57	1.73	4.46		
Controls	4.37	7.55	1.10	5.30		

*Average over patents with nonzero citations.

**Average over all patents

Table 10a: Poisson estimation of the citation lag model

	Coefficient (s.e.)			Coefficient (s.e.)			Coefficient (s.e.)			Coefficient (s.e.)		
	Cite lag quadratic for eco patents						*Cite lag quadratic for both*					
intercept	1.344	(0.620)	**	1.342	(0.616)	**	1.064	(0.207)	***	1.297	(0.561)	**
linear term	-0.147	(0.192)		-0.149	(0.191)		-0.052	(0.054)		-0.127	(0.188)	
quadratic term	-0.007	(0.012)		-0.007	(0.012)		-0.014	(0.004)	***	-0.009	(0.012)	
	Cite lag quadratic for controls											
intercept	1.027	(0.227)	***	1.223	(1.040)							
linear term	-0.037	(0.067)		-0.097	(0.336)							
quadratic term	-0.016	(0.006)	**	-0.012	(0.022)							
Test for cite lag distribution#	0.48 (0.923)			0.23 (0.973)								
Commons entry - ecopatents	-0.547	(0.267)	**	-0.552	(0.269)	**	-0.425	(0.157)	***	-0.538	(0.276)	*
Commons entry - controls				-0.149	(0.687)					-0.188	(0.384)	
Priority year dummie	yes			yes			yes			yes		
Log likelihood	-44,743,398.04			-44,743,398.16			-44,743,397.52			-44,743,397.91		

2280 observations on 184 = 90+94 equivalent groups.

Standard errors are robust and clustered on patents.

Robust chi-square (3) test for the equivalence of the cite lag distributions for ecopatents and controls.

Significant at the 1% (***), 5% (**) and 10% (*) levels.

Table 10b: Poisson estimation of the citation lag model

	Coefficient (s.e.)			Coefficient (s.e.)		
Cite lag quadratic for eco patents						
intercept	0.697	(0.540)		0.693	(0.548)	
linear term	-0.177	(0.155)		-0.175	(0.157)	
quadratic term	-0.005	(0.009)		-0.006	(0.009)	
Cite lag quadratic for controls						
intercept	-0.347	(0.250)		-0.391	(0.280)	
linear term	-0.022	(0.074)		-0.013	(0.079)	
quadratic term	-0.014	(0.006)	**	-0.015	(0.006)	**
Test for citelag distribution#	15.18 (0.002)		***	15.21 (0.002)		***
Commons entry - ecopatents	-2.504	(1.273)	**	-2.505	(1.300)	*
Commons entry - controls				-0.083	(0.333)	
Priority year dummies	yes			yes		
Log likelihood	-1,151,240.03			-1,151,240.09		

9309 observations on 711 = 238+473 patents.

Standard errors are robust and clustered on patents.

Robust chi-square (3) test for the equivalence of the cite lag distributions for ecopatents and controls.

Significant at the 1% (***), 5% (**) and 10% (*) levels.

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	671	0.447%	11,110	0.027%	4	884	0.452%	12,226	0.033%
1990	27	2,550	1.059%	27,060	0.100%	2	234	0.855%	15,519	0.013%
1991	9	801	1.124%	32,563	0.028%	1	232	0.431%	19,736	0.005%
1992	12	2,666	0.450%	32,471	0.037%	5	2,095	0.239%	20,346	0.025%
1993	13	7,548	0.172%	32,021	0.041%	1	1,058	0.095%	19,871	0.005%
1994	11	6,565	0.168%	31,550	0.035%	8	1,564	0.512%	19,280	0.041%
1995	22	8,990	0.245%	35,385	0.062%	7	2,702	0.259%	22,039	0.032%
1996	17	4,244	0.401%	38,876	0.044%	4	2,134	0.187%	23,903	0.017%
1997	13	13,093	0.099%	41,746	0.031%	9	3,792	0.237%	25,300	0.036%
1998	9	5,792	0.155%	43,655	0.021%	6	1,969	0.305%	25,552	0.023%
1999	11	7,475	0.147%	44,742	0.025%	5	959	0.521%	26,041	0.019%
2000	7	5,383	0.130%	48,938	0.014%	4	3,514	0.114%	27,078	0.015%
2001	11	19,940	0.055%	53,016	0.021%	5	8,096	0.062%	28,725	0.017%
2002	9	10,527	0.085%	46,109	0.020%	5	1,090	0.459%	25,772	0.019%
2003	6	4,666	0.129%	46,616	0.013%	3	1,454	0.206%	26,890	0.011%
2004	12	4,054	0.296%	46,653	0.026%	12	1,663	0.722%	27,832	0.043%
2005	32	5,378	0.595%	48,805	0.066%	9	875	1.029%	28,057	0.032%
2006	7	2,190	0.320%	18,459	0.038%					
2007	6	895	0.670%	2,574	0.233%					
2008	1	516	0.194%	1,871	0.053%					
2009	0	228	0.000%	498	0.000%					
Total	**238**	**114,172**	**0.208%**	**684,718**	**0.035%**	**90**	**34,315**	**0.262%**	**394,167**	**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	30,936	2.26	2.98	2.26	2.85	2.26	3.55
Dow	1	4,096	9.00	3.64	1.00	4.32	9.00	13.28
DuPont	11	11,949	3.91	3.43	5.73	3.71	79.09	6.31
FujiXerox	2	37,109	3.00	1.16	3.00	1.15	3.00	1.28
IBM	29	57,199	1.83	1.75	1.97	2.02	3.28	2.56
Mannesmann	1	2,602	2.00	2.72	2.00	2.56	2.00	3.35
Nokia	1	12,557	3.00	4.17	3.00	4.16	3.00	4.88
PitneyBowes	2	2,036	3.50	2.26	3.50	2.45	3.50	2.98
Ricoh	1	97,139	1.00	1.13	1.00	1.11	1.00	1.49
Sony	4	119,207	1.00	1.55	1.00	1.48	4.50	1.94
Taisei	2	6,770	1.00	1.02	1.00	1.02	1.00	1.04
Xerox	13	12,567	4.31	2.27	4.92	2.49	6.92	3.06
All	**90**	**394,167**	**2.64**	**1.74**	**2.91**	**1.76**	**12.83**	**2.36**

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%	12,459	10.9%	76,727	11.2%	24	25.0%	3,547	10.3%	31,897	8.1%
JP Japan	34	14.3%	20,315	17.8%	281,703	41.1%	10	10.4%	8,912	26.0%	260,034	66.0%
US USPTO	75	31.5%	30,746	26.9%	141,319	20.6%	59	61.5%	21,679	63.2%	85,950	21.8%
Other	84	35.3%	50,652	44.4%	184,969	27.0%	3	3.1%	177	0.5%	16,286	4.1%
Total	**238**		**114,172**		**684,718**		**96**		**34,315**		**394,167**	

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 patents with missing legal status as not granted and not in force/pending

Appendix Table 5: Average forward citations by citation lag

unit of analysis: patent					unit of analysis: equivalence group				
Lag	*controls*	*ecopats*	*before*	*after*	*Lag*	*controls*	*ecopats*	*before*	*after*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
0	0.1501	0.1513	0.151	0	0	0.681	0.400	0.400	0
1	0.1649	0.1639	0.164	0	1	0.819	0.433	0.433	0
2	0.1755	0.2647	0.265	0	2	0.862	0.711	0.711	0
3	0.1459	0.2689	0.269	0	3	0.702	0.689	0.689	0
4	0.1290	0.2479	0.239	0.0084	4	0.617	0.633	0.611	0.022
5	0.0888	0.1597	0.160	0	5	0.436	0.378	0.378	0
6	0.0749	0.1182	0.118	0	6	0.360	0.313	0.313	0
7	0.0638	0.1075	0.108	0	7	0.321	0.319	0.319	0
8	0.0539	0.1160	0.110	0.0055	8	0.293	0.258	0.242	0.015
9	0.0325	0.0930	0.087	0.0058	9	0.149	0.262	0.246	0.016
10	0.0224	0.0864	0.080	0.0062	10	0.117	0.250	0.232	0.018
11	0.0103	0.0329	0.020	0.0132	11	0.054	0.096	0.058	0.038
12	0.0000	0.0352	0.035	0	12	0.000	0.106	0.106	0
13	0.0100	0.0000	0.000	0	13	0.049	0.000	0.000	0
14	0.0303	0.0085	0.008	0	14	0.172	0.031	0.031	0
15	0.0199	0.0180	0.018	0	15	0.115	0.071	0.071	0
16	0.0072	0.0000	0.000	0	16	0.050	0	0.000	0
17	0.0000	0.0282	0.028	0	17	0	0.154	0.154	0
Total	0.085	0.130	0.128	0.0022	Total	0.424	0.363	0.357	0.0063

Kruskal-Wallis chi-squared = 26.30 (0.000) for same distribution
Ranksum test = 5.13 (0.000) for same distribution

Kruskal-Wallis chi-squared = 1.27 (.260) for same distribution
Ranksum test = 1.13 (0.260) for same distribution