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GREEN TECHNOLOGY DIFFUSION:
A POST-MORTEM ANALYSIS OF THE ECO-PATENT COMMONS

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ABSTRACT

We revisit the effect of the "Eco-Patent Commons" (EcoPC) on the diffusion of patented environmentally friendly technologies following its discontinuation in 2016, using both participant survey and data analytic evidence. Established in January 2008 by several large multinational companies, the not-for-profit initiative provided royalty-free access to 248 patents covering 94 "green" inventions. Hall and Helmers (2013) suggested that the patents pledged to the commons had the potential to encourage the diffusion of valuable environmentally friendly technologies. Our updated results now show that the commons did not increase the diffusion of pledged inventions, and that the EcoPC suffered from several structural and organizational issues. Our findings have implications for the effectiveness of patent commons in enabling the diffusion of patented technologies more broadly.

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1. Introduction

Although patents give their owners the right to exclude others from practicing a patented technology, or to charge them for the privilege of doing so, an increasing number of firms across different industries have begun to make voluntary pledges intended to limit their ability to enforce their patents to the fullest degree (Contreras, 2015). Yet the pledging of patents, even to the extent that they will not be asserted against infringers, stops short of abandoning or contributing them to the public domain.[4] Thus, under a pledge model, also referred to as patent commons, patent assets are retained by their owners, who continue to incur maintenance and other fees, but the use of such patents for the traditional exclusionary purpose is significantly curtailed.[5]

Patent commons differ from other mechanisms used to share patents, including cross-licensing agreements or patent pools in important ways. For example, in both cross-licensing agreements and patent pools, access to patents is granted only to participating companies, although in the case of patent pools, outsiders often can also access the pooled patents for a fee. The main difference between these structures and a patent commons, therefore, is that the commons typically confers benefits on all third parties, regardless of their contribution to the commons and typically without a formal contract.

Patent pledges are made for a variety of reasons, including the promotion of broad product interoperability through common technical standards, the advocacy of new technology platforms, and the pursuit of social goals (Contreras, 2015 and 2018). Over the past few decades, significant patent pledges have been made in areas such as open source software (e.g., IBM, Sun, Google and Red Hat have each pledged that they will not assert hundreds of patents against open source software implementations), electric vehicles (Tesla Motors' famous proclamation that "All our patents are belong to you"(*sic*)), and biotechnology (e.g., Monsanto's pledge not to assert patents covering genetically modified seeds against farmers inadvertently growing them) (see, generally, Contreras, 2015 and 2018). Over the years, some collective patent pledges, pledge communities and patent commons have achieved significant adoption in the marketplace, while others have not. For example, from its inception in 2014 through late 2017, Google's License on Transfer (LOT) network, in which patent holders commit not to transfer their patents to patent assertion entities (PAEs), attracted 180 members and more than 180,000 patents (LOT 2018). In contrast,

[4] Several large patent holders, including IBM, have a well-articulated strategy for abandoning unused patents (Crouch, 2012). Other coordinated industry efforts, particularly in the biomedical sector, have contributed substantial intellectual property assets to the public domain for a variety of reasons (Contreras, 2014).

[5] Patent pledges, including the Eco-Patent Commons, usually contain so-called "defensive suspension" provisions that allow pledging companies to deny royalty-free access to other companies that assert their patents against the pledging firm. By itself, this phenomenon suggests that some patents are held for purely defensive purposes rather than as exclusionary rights.

the Defensive Patent License (DPL) network, which was launched in the same year with similar goals, has attracted few members (Contreras 2018). The differences in take-up between these two pledge communities can be attributed to a variety of factors including internal governance mechanisms, commitment details and evangelization (Contreras 2018)

The Eco-Patent Commons (EcoPC) was an innovative not-for-profit initiative undertaken by a small group of large industrial firms with the goal of pledging "green technology" patents for broad, royalty-free use in addressing environmental challenges. The thirteen EcoPC participants collectively pledged a total of 248 "green technology" patents (94 priority patents or distinct inventions) to the EcoPC between its formation in 2008 and its discontinuation in 2016.[6]

The EcoPC had the ambitious objective of promoting the diffusion of green technologies to increase and accelerate their adoption and to encourage follow-on innovation. The theoretical mechanism to achieve all this is simple: by removing a patent owner's ability to assert a patent against any users of the patented technology, the technology -- which had been already disclosed by the patent publication -- becomes available for royalty-free use to any interested party. In principle, this addresses the well-known welfare cost associated with temporary market power granted by patents that likely slows the diffusion of patented technology (Hall and Helmers, 2010).

Following its creation, the EcoPC attracted substantial attention in both the scholarly literature (Mattioli, 2012; Hall and Helmers, 2013; Awad, 2015; Contreras, 2015) and the popular media (Tripsas, 2009). In addition to accolades, the EcoPC attracted some skepticism regarding its potential effectiveness. The skepticism focused on whether a commons could offer sufficient incentives to attract valuable patent pledges and thereby achieve its ambitious goals. In contrast to other mechanisms designed to share patents, such as cross-licensing and patent pools, patent owners in the EcoPC committed to maintain ownership of their patents (which is costly) while making those patents freely accessible to third parties including competitors. Some competitive safeguards were left in place, notably a defensive termination right in case a different patent was asserted against the pledger by another firm using the patented technology. For these reasons, it was not obvious what benefits the commons offered to participants beyond reputational enhancement. This in turn meant that participants could have had incentives to minimize their costs by pledging only patents with little commercial value and allowing them to lapse shortly after they were pledged. A second possible benefit might be that those building on

[6] Patents are territorial rights, that is, separate patents on the same invention have to be obtained in each jurisdiction where patent protection is sought. This means that there often exist multiple patents on the same invention, which are referred to as equivalents or patent family. The priority patent describes the first patent filing within a given set of equivalents.

these technologies might find other (commercial) outputs of the contributing firm useful, or might add to a knowledge base from which the firm would benefit.[7]

In an earlier study (Hall and Helmers 2013), we studied the characteristics of the patents pledged to the EcoPC. This study confirmed that the pledged patents did claim environmentally friendly technologies. Moreover, pledged patents were of similar value to other patents in the pledging firm's portfolio, but of lower value than other patents in their class, using the usual patent value indicators (based on citations, family size, number of patent technology classes, etc.). The findings suggested that the EcoPC participants might have pledged patents with the potential to diffuse environmentally friendly technologies that were possibly useful to other firms and researchers.

To study whether the EcoPC increased the diffusion of green technologies, Hall and Helmers (2013) looked for changes in forward citations to pledged patents following their addition to the commons. They constructed a set of control patents that matched the publication authorities, priority years, and technology classes of the EcoPC patents. They examined the pattern of citations by subsequent patent applications to the set of EcoPC patents and their controls over time, before and after contribution and found that the EcoPC patents tended to be cited *less* than the patents in the control group *before* contribution to the EcoPC. However, the results after contribution were inconclusive, because most of the patents were contributed in late 2008 and there was little data post-pledge as citation data was available only through early 2012, leaving little more than 3 years of citation data post-pledge.

In the current study, we revisit the effect of the EcoPC on technology diffusion and assess its impact more broadly, using several approaches. The first is a set of interviews with participants in the EcoPC and those responsible for it, described in Section 3 of this paper. These interviews provide helpful qualitative information that allows us to better understand the underlying causes of the EcoPC's failure to encourage diffusion of pledged technologies. The second is an updated look at the data on the patents pledged to the EcoPC, described mainly in sections 4 and 5. With the passage of time, substantially more citation data has become available (through 2016 as opposed to early 2012 in Hall and Helmers (2013)). This allows us to reexamine the data and provide a more definitive answer to the question whether the commons has had any effect on technology diffusion, at least as reflected in subsequent patenting. The fact that the EcoPC was discontinued in 2016 while during the same time several new commons were created also motivates us to revisit the viability of such patent commons more generally. Finally, we asked inventors of

[7] Belenzon (2006) shows that focal firm citations to patents that cite a focal firm's patents are positively valued by the market, suggesting this kind of feedback effect from others' use of the firm's technology.

the patents that cite any of the EcoPC patents after they were pledged about the role that the pledge has played in their decision to rely on an EcoPC patent as prior art.

To summarize our main findings: we do not find any evidence that the EcoPC increased the diffusion of pledged patents. Pledged patents are cited less than the matched control patents before they enter the commons, suggesting that they were already less valuable, and their pledge does not change this. Inventors of citing patents unanimously indicated that the pledge, i.e. royalty-free access, did not affect their decision to rely on an EcoPC patent as prior art. In fact, none of the inventors that responded to our query were even aware that the cited patent was part of the EcoPC and hence royalty-free access played no role in their decision to rely on it as prior art. These results suggest that the commons had no effect on technology diffusion. Looking at the EcoPC priority patents, 82 per cent had lapsed by July 2017 due to expiration (26 per cent), rejection or withdrawal (18 per cent), or non-payment of renewal fees (38 per cent). This indicates that participating companies in most cases did not consider the benefits of the commons sufficiently large to maintain the patents in force and expired patents were not replaced by new patent pledges. Our interviews with representatives of the EcoPC participants reveal several common critiques of the EcoPC's structure and operational processes that help explain our quantitative findings, particularly EcoPC's inability to provide information regarding the usage of contributed technologies.[8] Another major impediment to diffusion was the lack of information provided by pledging companies beyond the patent documents that could have helped potential users (especially in developing countries) see potential applications of the pledged technologies. Finally, no concerted effort was made to group or link patents in the commons to any particular technology. This lack of coordination may have limited synergies that could have been created through a more deliberate approach to the technologies covered by contributed patents.

This study both updates our previous work and fills gaps in our understanding of the functioning and performance of the EcoPC and patent commons more generally. Providing a more definitive answer to the question of diffusion and the functioning of the EcoPC more broadly is important for several reasons. First, it offers insight regarding the manner in which patent pledges can support the diffusion and implementation of (green) technologies around the world. Second, it can inform the design of other pledge communities both in the environmental space and other key technology areas, such as electric vehicles, software, biotechnology, and agriculture. Third, it informs us more generally about the viability of patent commons created by for-profit companies as a mechanism to share access to patented technology

[8] This feature of the commons also limits our ability to study their subsequent use, which is why we chose to focus on citations to these patents, which is public data.

The remainder of this article is structured as follows. Section 2 reviews the institutional design and history of the EcoPC. Section 3 summarizes the findings from our interviews of participants in the EcoPC. In Sections 4 and 5 we turn to a quantitative analysis of these patents and their citations and discuss the results of our inventor survey. Section 6 offers a few concluding thoughts that emerge from our analysis for the design and functioning of patent commons.

2. The Eco-Patent Commons: Structure and Development[9]

The concept for the EcoPC as a collective mechanism for permitting broad usage of patents covering environmental technologies was originally developed by IBM in the mid-2000s as one of several corporate initiatives directed toward environmental protection and sustainability (IBM 2010). Given IBM's well-known patent strength,[10] a program to promote environmental causes would capitalize on one of the company's principal assets. IBM had already made significant commitments to the sharing of patents and other intellectual property (IP) in the area of open source code software (Merges 2004; Wen et al. 2013; Contreras 2015). Accordingly, extending these initiatives to the environmental area was consistent with IBM's existing corporate culture.[11]

The idea behind the EcoPC is that industrial firms with large patent portfolios likely hold patents covering technologies with environmental applications, but because those technologies are not core to the firm's business, they are languishing unused. If, however, the patents covering these technologies could be made freely available to users around the world, then a significant public service could be rendered at a minimal cost to the patent holder.

IBM publicly announced the concept for the EcoPC at its Global Innovation Outlook conference in 2006 (IBM 2008). It then initiated discussions with other large firms with which it had existing business ties and which it believed might be sympathetic to a collective approach to making environmental technologies more broadly available. In January 2008, IBM announced the launch of the EcoPC together with Nokia, Pitney Bowes

[9] The material in this section is derived both from the works cited and also from the interviews described in Part 3, below. Additional information regarding the organization and history of the EcoPC can be found in Mattioli (2012), Hall and Helmers (2013) and Awad (2015).

[10] According to U.S. Patent and Trademark Office statistics, IBM regularly receives more U.S. patent grants than any other company in the world, about 7,000-8,000 patents per year in 2014-2016.

[11] The EcoPC explicitly compared itself to the open source movement, noting in its promotional materials "As has been demonstrated by the open source software community, the free sharing of knowledge can provide a fertile ground for new collaboration and innovation. Sharing environmental patents can help others become more eco-efficient and operate in a more environmentally sustainable manner—enabling technology innovation to meet social innovation." (EcoPC 2017).

and Sony (IBM 2008). A total of thirteen firms eventually joined the EcoPC as summarized in *Table 1*, below.

Table 1: Firm Participation in the EcoPC

Firm	Date Joining EcoPC	No. Patents Pledged*
IBM	Jan. 14, 2008	29
Nokia	Jan. 14, 2008	1
Pitney Bowes	Jan. 14, 2008	2
Sony	Jan. 14, 2008	4
Bosch	Sept. 8, 2008	24
DuPont‡	Sept. 8, 2008	11
Xerox	Sept. 8, 2008	13
Taisei	Mar. 23,2009	2
Ricoh	Mar. 23, 2009	1
Dow	Oct. 20, 2009	1
Fuji Xerox	Oct. 20, 2009	2
Hewlett-Packard	July 1, 2010	3
Hitachi‡	July 25, 2011	1
* Priority patents (i.e. patent families).		
‡ DuPont and Hitachi withdrew from the EcoPC in 2013, as of the transfer of management from WBCSD to ELI.		

The stated mission of EcoPC was "to manage a collection of patents pledged for unencumbered use by companies and IP rights holders around the world to make it easier and faster to innovate and implement industrial processes that improve and protect the global environment." (EcoPC, 2013b). Accordingly, patents eligible for inclusion in the EcoPC were required to belong to one of sixty enumerated International Patent Classification (IPC) codes[12] relating to environmental or sustainability technology. Technologies sought by the EcoPC included energy conservation, pollution control, environmentally-friendly materials, water or materials use or reduction, and recyclability (EcoPC, 2013b). 248 patents were pledged to the EcoPC, with the last such contribution occurring in 2011 (see Part 4 below).[13]

To pledge a patent to the EcoPC, the owner was required to make an irrevocable covenant not to assert the patent – or "any worldwide counterparts" (EcoPC, 2013a) -- against any infringing machine, manufacture process or composition of matter that "reduces/eliminates natural resource consumption, reduces/eliminates waste generation or pollution, or otherwise provides environmental benefit(s)." (EcoPC, 2013a). This being

[12] The IPC system divides technologies into eight principal sections with approximately 70,000 subcategories.

[13] This number is arrived at as follows: there were 238 patents pledged at the time of our work in Hall and Helmers (2013). Since then, Hewlett-Packard added 9 and Hitachi 1, for a total of 248.

said, patent owners retained the (defensive termination) right to assert pledged patents against (a) any EcoPC participant that asserted any environmental patent against them, or (b) any non-EcoPC participant that asserted any patent against them (EcoPC, 2013a).[14]

The initial administrator of the EcoPC was the World Business Council for Sustainable Development (WBCSD), a Geneva-based non-governmental organization focused on environmental and sustainability issues. WBCSD's initial duties consisted primarily of hosting the EcoPC web site and promoting EcoPC to other WBCSD members for purposes of recruitment. WBCSD publicized the EcoPC among its members and attracted several of the participants that joined following the EcoPC's formation (see Table 1).

Participation in the EcoPC was open to all individuals and companies in the world, the only requirement for participation being the pledging of one or more patents according to the EcoPC's rules.[15] Neither membership in WBCSD nor any additional dues or charges were required for EcoPC participation. The EcoPC itself was characterized as an unincorporated, non-profit association (EcoPC, 2013b).

In 2013, the administration of EcoPC was transferred from WBCSD to the Environmental Law Institute (ELI), a Washington, D.C.-based trade and advocacy organization. This transition was apparently orchestrated by IBM, which had withdrawn as a member of WBCSD, thereby eliminating the primary driver of WBCSD's involvement. ELI, of which IBM was a significant member, hosted the EcoPC web site from 2013 through 2016, but was not actively engaged in recruiting new participants. Two EcoPC members, Hitachi and DuPont, withdrew from the EcoPC at the time of this administrative shift. No new patents were contributed to the EcoPC after Hitachi's initial 2011 contribution. By 2016, very little activity was occurring at the EcoPC. Accordingly, in 2016, the EcoPC was formally discontinued (EcoPC, 2016).[16]

Though the EcoPC has been shut down, pursuant to the EcoPC Ground Rules and pledge terms, the "irrevocable" non-assertion pledge made with respect to each pledged patent will continue in accordance with its terms indefinitely.[17]

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[14] This is a so-called "defensive termination" provision.

[15] Members of the EcoPC were required to complete a Membership Application/Pledge Form which bound them to comply with the EcoPC's Non-Assert Pledge, Ground Rules and Governance Structure (EcoPC, 2013a).

[16] Based on our interviews (see Part 3 below), we understand that each EcoPC participant was consulted by IBM regarding the decision to wind-down the EcoPC. Apparently there was no resistance to this course of action.

[17] The Ground Rules make it clear that a patent owner's EcoPC pledge will survive that owner's withdrawal from the EcoPC (EcoPC 2013a ("voluntary or involuntary withdrawal shall not affect the non-assert as to any approved pledged patent(s) – the non-assert survives and remains in force"). For example, Hitachi pledged a

3. Interviews

This section of the paper describes the results of a series of semi-structured interviews with representatives of participating companies, WBCSD and ELI.[18] Here we focus on the strengths and weaknesses of the EcoPC that were identified by interviewees with a view to informing our interpretation of our quantitative results on the diffusion of pledged technologies. Additional findings from our interviews are summarized in Contreras et al. (2018).

3.1 Methodology

We identified individuals employed by EcoPC corporate participants who had been personally involved with their employer's decision to join the EcoPC and/or its ongoing participation in the EcoPC. Through online searches and informal inquiries we were able to obtain valid and current contact details for representatives of nine of the thirteen EcoPC corporate participants. Seven of these individuals consented to be interviewed for this study (five by telephone and two by written correspondence).[19] In addition, we interviewed representatives of WBCSD and ELI who were directly involved in EcoPC activities.[20]

The information gathered in this way is not necessarily representative of the views held by all member companies of the EcoPC as there is the possibility that interviewees selected into our sample based on their own, subjective views of the performance of the EcoPC. That said, we obtained information from a relatively diverse sampling of company representatives (relative to the number of people involved in the project) across different geographical regions (companies based in the U.S., Europe and Japan) and are therefore optimistic that these interviews offer relevant information with regard to at least a significant portion of the EcoPC participants' views regarding the organization.

patent to the EcoPC in 2011, but withdrew from the EcoPC in 2013. This patent should remain pledged. See Contreras (2015: 598).

[18] Interviews were conducted by Contreras pursuant to a determination of "no human subject research" by the University of Utah Institutional Review Board (Jun. 26, 2017, IRB 00102447). Interview subject information is held by Contreras.

[19] The authors have agreed not to disclose the identities of either the individuals interviewed or the EcoPC participant companies that they represented, with the exception of IBM, given its central role in forming and managing the EcoPC.

[20] Interview scripts differed for individuals representing EcoPC participants versus administrators. Each interview lasted approximately thirty to sixty minutes. Responses were coded by the interviewer. No compensation was offered to interview subjects.

3.2 Findings

Most respondents viewed the EcoPC as a valuable demonstration of corporate willingness to collaborate to achieve environmental and sustainability goals. The public relations benefits of EcoPC participation were also viewed as valuable by some companies. However, each of the respondents expressed dissatisfaction with at least some aspects of the EcoPC which help explain its failure to encourage the diffusion of the pledged technologies and ultimately the EcoPC's shutdown:

a. *Membership and Recruitment*. At its height in 2011, the EcoPC had thirteen corporate participants. Though these firms were all major global enterprises with large patent portfolios, they still represented only a tiny fraction of the total potential membership in the organization. Particularly given that the EcoPC charged no membership fee, it was somewhat puzzling that so few firms joined. While WBCSD did appear to promote membership in the EcoPC, few of WBCSD's many members elected to join. Based on our discussions with EcoPC members, we believe that possible impediments to recruitment were (a) the perceived difficulty and expense of identifying suitable patents for contribution, (b) a belief among potential members that they lacked patents that were suitable for contribution, and (c) an aversion to the idea of contributing potentially valuable patents to the EcoPC without compensation, a view generally held by legal and IP departments.

b. *No Tracking of Usage*. All respondents observed that there was no effective way to determine whether the technologies covered by patents pledged to the EcoPC had been utilized.[21] As a result, it was difficult for them to draw conclusions regarding whether the EcoPC was worth the effort, and to determine whether the goals of improving environmental conditions and sustainability were being met. Moreover, without clear success metrics, it was difficult to justify devoting ongoing effort to the EcoPC to upper management at some companies. Several respondents indicated that the EcoPC made a conscious decision *not* to require users to register with the web site or report back to the EcoPC, as it was felt that such requirements would serve as barriers to use of the web site.

WBCSD, at least initially, tracked hits to the EcoPC web site and shared this information with the participants.[22] However, as noted above, identifying information about visitors was not collected, and it was not clear whether visitors were academics, students, attorneys, journalists or potential users of technology.

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[21] This weakness was identified by commentators soon after the EcoPC's formation (Bowman, 2009).

[22] We analyzed the data on web hits in our earlier study to find a highly skewed distribution of hits, only 36 patents received any hits. Nevertheless, the analysis also indicated a positive correlation between web hits and forward citations by other patents (Hall and Helmers, 2013).

c. *Website not User-Friendly*. It was noted that the cataloging of patents on the EcoPC web site, which was organized by contributing company rather than technology area, was not particularly intuitive or informative. It required potential users to look up the relevant patents one by one in order to understand the technology being offered. Moreover, usually only a single patent family member was listed, requiring users to identify the remaining members themselves. This procedure would have required both substantial effort on the part of potential users, as well as a high degree of familiarity with the format and terminology of patent documents.[23] As documented by Hall and Helmers (2013), the website also listed a number of erroneous patent numbers, another potential source of frustration for users.

d. *No Technology Transfer*. Another issue raised by several respondents was that the EcoPC sought to promote the dissemination of green technologies through patents alone. Yet complex technologies often cannot be understood and implemented, especially by non-experts working in the developing world, only through patent disclosures (McManis and Contreras 2014). Some form of technology assistance or transfer is generally required to enable local users to take advantage of patented technologies, or even to realize that such technologies are available and applicable to local problems. One of the issues that emerged in this regard was uncertainty regarding the intended users of the EcoPC system.

Several of the individuals we interviewed believed that intended users of EcoPC technology would be from the developing world. Yet this belief evidences a misunderstanding of the global patent system. Patents prevent usage of a patented technology only in the countries where patents are issued. Most companies do not seek patent protection in the least-developed countries, either because protection is uncertain in those countries, or because their markets are underdeveloped and the cost of procuring patent protection is not viewed as cost effective. Even in middle income countries, multinationals tend to focus on pharmaceutical patenting and patenting in specific areas where the country in question is competitive (Hall and Helmers 2018; Abud et al. 2013). Accordingly, many technologies that are patented in the developed world are not themselves patented in the developing world. This general rule certainly applies to the patents contributed to the EcoPC, most of which have "family" members throughout the developed world (North America, Europe, Asia Pacific – see Table 4 below), but few if any patent family members in the developing world. Thus, organizations in the developing world *already* have the right to seek to exploit many technologies disclosed in patents filed in the developed world. But they do not do so because, as discussed above, the utilization of even moderately complex technologies is not possible without significant training and technology transfer activity that is not

[23] It is worth pointing out that this situation is changing rapidly at the present time, since Google patent search now includes the members of the patent family in its results. However, this feature was not available during most of the life of the EcoPC.

accomplished through the grant of patent rights alone. In addition, technologies patented in the developed world may not be targeted to needs in the developing world without extensive further development.

4. Data

For the purpose of our quantitative analysis in Section 5 below, we updated the database used in Hall and Helmers (2013). This means that for comparison purposes, we restricted the set of patents to all patents pledged prior to July 2010, which excludes the 4 families pledged by Hewlett-Packard and Hitachi.[24] We also included the original control patents, which had been obtained by propensity score matching on priority year, IPC subclass, and publication authority.

Updating the data turned out to be somewhat complex, partly because the original data were drawn from a PATSTAT version with non-permanent identifiers, and partly because PATSTAT itself changes over time, with some data disappearing due to changes in the data at the contributing national or regional patent offices. In addition, the list of patents on the EcoPC website appears to have changed slightly, to some extent in response to our comments on the original list (incorrect numbers, etc.). We used the April 2017 PATSTAT version and identified a correspondence between the prior identifying numbers and the permanent (as of April 2011) identifiers using information on the application number and authority of the relevant patents. In a few cases, we were unable to find the application number-authority combination on the new version of PATSTAT. There were 4 such applications from the Japanese Patent Office (JPO), which apparently had been withdrawn and are no longer on their website.[25] We included them in our forward citation analysis as having zero cites, for completeness. In addition, 24 applications from the Australian Patent Office (APO) were reduced to 12 applications in the new PATSTAT file. Most of these problems affected the control patents rather than the Eco-patents.

The resulting dataset contains 698 applications rather than the original 711, with the distribution shown in Table 2.

[24] In the case of the Hitachi patent, it is not clear that the patent was ever listed on EcoPC's public web site. All versions of the EcoPC list of patents that we were able to locate using web archive tools were current only as of May 2011, prior to Hitachi's joining.

[25] One problem with searching for JPO patents, especially the earlier ones, is that the numbering systems are quite complex and some numbers are apparently reused occasionally (See http://www.searchpriorart.com/search_tips/patent_no_search.htm for further information on Japanese patent numbering). This problem leads to apparent errors on the Espacenet and Google patents websites. We also found that at least two of the equivalent patents we had identified for the controls became utility model patents when they were granted in Japan.

Table 2: Dataset construction

	Old (2011 data)	*New (2017 data)*
Number of applications	711	698
Controls	473	461
Eco-patents	238	237
Num of equivalence groups	184	184
Controls	94	94
Eco-patents	90	90
Number of citations	1872	4056
Controls	1205	2713
Eco-patents	667	1343

Note: Controls matched based on the publication authorities, priority years, and IPC classes of the EcoPC patents.

From Table 2, one can see that although the set of applications has changed slightly, we still have the same number of equivalent groups for the patents to be analyzed. It is also clear that the number of citations to both the EcoPC patents and controls has grown considerably, more than doubling in both cases (see Section 5.2 below for further analysis of the citations).

For our inventor survey, we extracted from PATSTAT the names of all inventors of all 329 patents that cited an EcoPC patent after the patent had been pledged to the commons. We then focus only on those patents where the citation to the EcoPC patent was not added by the examiner (see also Section 5.2). This left us with 141 patents (43 per cent). After undertaking some name cleaning and harmonization, we obtained a total of 271 inventors. We then searched the web for their contact information. We were able to send our short questionnaire, which consisted of only three questions, to 71 (26 per cent) inventors. We obtained responses from 13 inventors, a response rate of 18 per cent. However, only 10 of these 13 inventors agreed to answer our questionnaire. These 10 inventors worked for four different EcoPC member companies: three inventors worked for Bosch, three for IBM, three for DuPont and one for Xerox. These are the four firms that contributed the largest number of patents to the commons (Table 2). We summarize the results briefly in section 5.2 below.

5. Empirical results

In this section, we use the data on patents pledged to the EcoPC and their matched controls to analyze (1) the legal status of EcoPC patents to gauge whether member companies considered continued ownership of their pledged patents as sufficiently important to incur the associated costs and (2) the diffusion of the technologies protected by patents pledged to the EcoPC as measured by citations received from other patents.

5. 1 Legal status of the pledged patents

We begin by looking at the legal status of the EcoPC pledged patents as of July 2017, summarized in Table 3. We collected these data from PATSTAT's legal status tables of April 2017 and supplemented the information using web searches. The WO (PCT) patents in our database will not have a post-grant legal status since they are granted on a national basis, and a few patent applications from the JPO could not be found, probably because the PATSTAT entries were for translations or they were utility model applications in Japan, even though they might have been patent applications elsewhere. There are 15 such patents for which we do not have legal status, or legal status is meaningless. Of the remaining 221 patent applications, almost 20 percent of the 90 priority patents were still in force as of July 2017, but only 11 percent of all the equivalent patents. Of the 27 patents still in force or pending, 12 are US patents, 6 are Japanese, 4 are European Patent Office (EPO) or German, and the remainder are Chinese (1), Russian (2), Mexican (1), and Korean (1). Almost half the patents have expired for nonpayment of fees, although almost as many expired at the end of their terms.

Table 3

Legal status of eco-patents - July 2017

	All	*Priority*	*All*	*Priority*
pending	8	3	3.4%	3.3%
granted and in force	19	14	8.1%	15.6%
Total still active	**27**	**17**	**11.4%**	**18.9%**
nonpayment of fees	90	29	38.1%	32.2%
expired at term	61	30	25.8%	33.3%
rejected	18	7	7.6%	7.8%
withdrawn	24	7	10.2%	7.8%
Total not active	**193**	**73**	**81.8%**	**81.1%**
Missing (from JPO)*	5	0	2.1%	0.0%
WO applications	11	0	4.7%	0.0%
Total	**236**	**90**		

* These appear to be translation entries or utility models.

In Figure 1, we show the distribution of patent lifetimes (approximated by the lapse (expiration or nonpayment) dates minus the application filing date).[26] In the case of patents still in force, we measured the lifetime to July 2017. The distribution is fairly flat for those patents that did not remain in force for their full terms. A substantial number of patents remained in force for either the full 20-year patent term or a significant portion of it. This suggests that in many cases, companies decided to pay renewal fees to keep the patents in force even after they had been pledged to the EcoPC.[27] For example JP4696713 "Wastewater treatment process" by Fuji Xerox is still in force in 4 out of 5 jurisdictions in which it was filed. Other patents still in force include Sony's JP3876497 "Flocculating agent and a method for flocculation" which was granted in early 2007 or IBM's US6294028 "Mercury process gold ballbond removal apparatus" which was granted in 2001 and maintained in force throughout the entire lifetime of the EcoPC. However, there are also patents such as US5050676 "Apparatus for two phase vacuum extraction of soil contaminants" owned by Xerox; the patent has 5 equivalents, 4 of which had expired before the patent was pledged, and the remaining patent expired at term less than a year and a half after the patent was pledged and no maintenance fees were payable during that time. This is an example of the pledge of a patent that had most likely no longer any value to the company.

[26] Most offices now have a common patent term: 20 years from filing date, but there are various exceptions, and older patents in our sample may have been issued under different rules. When we were able to obtain the actual expiration date, we used that (most cases).

[27] Renewal fees usually increase over time, at the USPTO for example, large entities pay US$1,600 to maintain a patent inforce after 4 years after grant and US$7,400 12 years after grant.

Figure 1

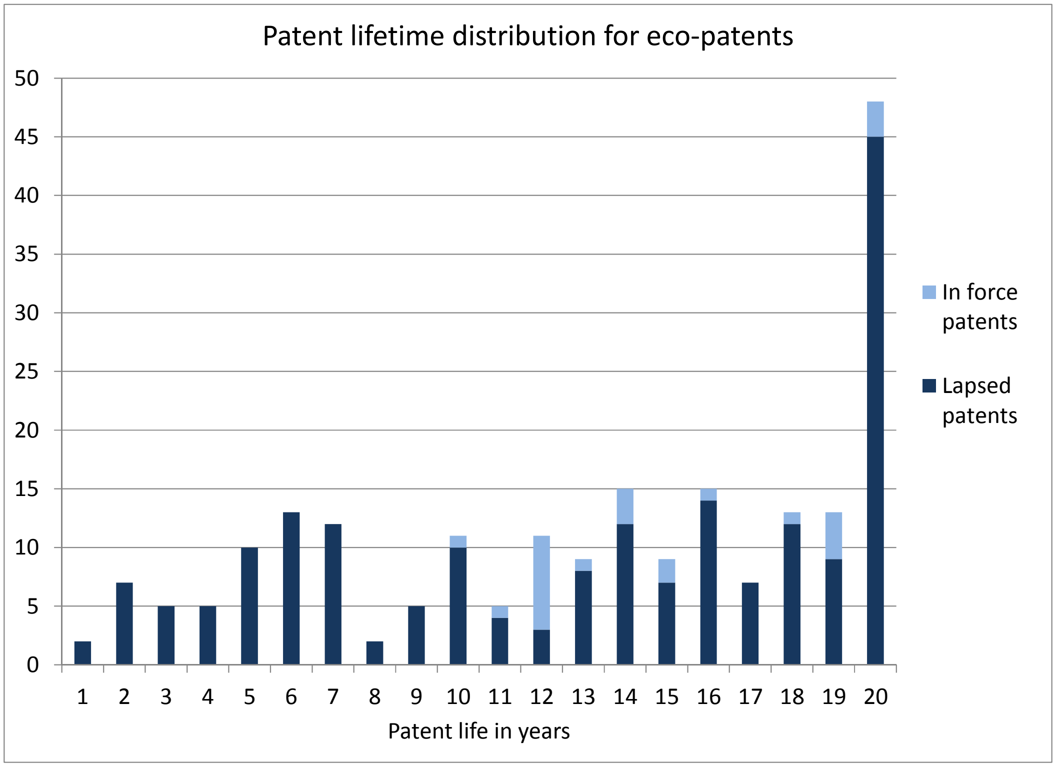

Figure 2 breaks down the different reasons why patents lapsed. It shows that a significant number of patents have expired since 2007, the year before the EcoPC was launched. A few patents were rejected by the relevant patent offices or were withdrawn by applicants, but the majority lapsed due to non-payment of renewal fees.

Figure 2

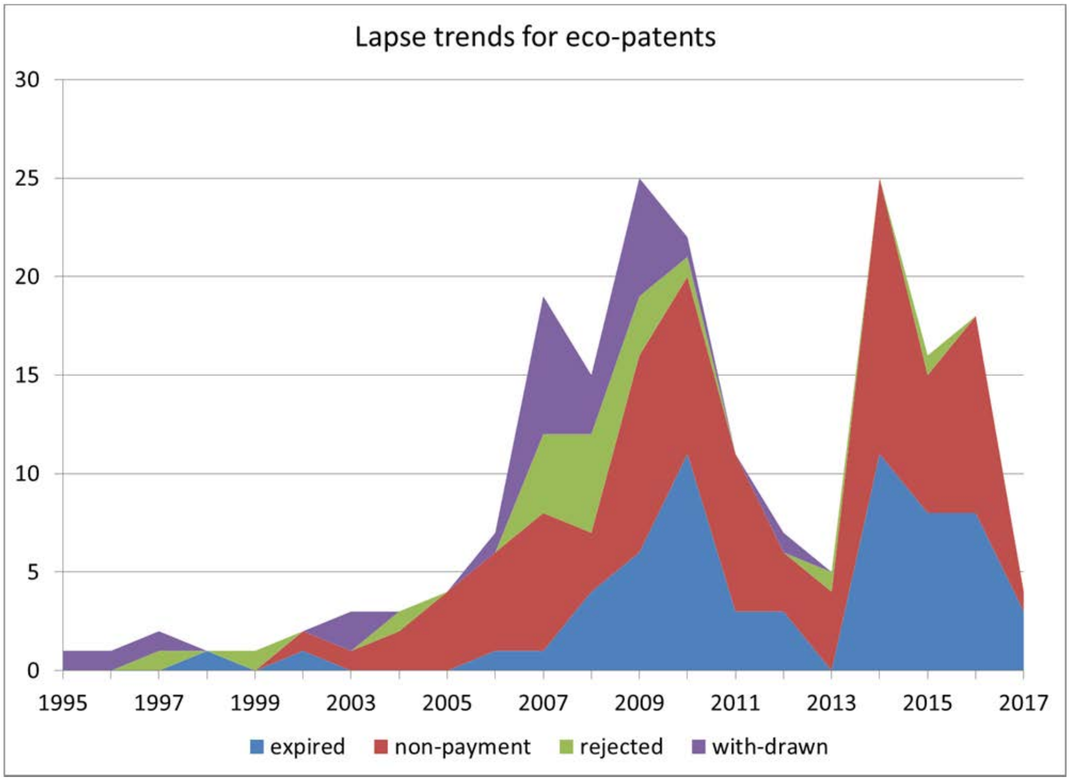

Table 4 shows the geographic coverage of the EcoPC patents. 90 percent of the priority patent applications were made to the 4 most important jurisdictions: the US, Germany, Japan, and the EPO, and these jurisdictions account for 80 percent of the patents overall. There is very little evidence that the patents in the commons ever covered less-developed countries. The only patents in middle income countries are in Brazil (7), Mexico (4), and Argentina (1), and there are none in low income countries. So patents cannot have been an obstacle to the use of technologies in less-developed countries.

Table 4: Application authority distribution

Application authority distribution			
Authority		*Priorities*	*All*
USA	US	34	75
Germany	DE	20	45
Japan	JP	17	34
EPO	EP	10	34
South Korea	KR	2	7
China	CN	2	3
Austria	AT	1	4
Spain	ES	1	4
UK	GB	1	2
Norway	NO	1	2
Denmark	DK	1	1
Brazil	BR		7
Canada	CA		7
Mexico	MX		4
Australia	AU		2
Russia	RU		2
Argentina	AR		1
France	FR		1
Hong Kong	HK		1
Israel	IL		1
Total		**90**	**237**

5.2 Technology diffusion and follow-on innovation

Next we reexamine the question of technology diffusion by looking at the updated citation data. Our analysis in Hall and Helmers (2013) suggested that pledged patents protect environmentally friendly technologies that could have the potential to be adopted for use by third parties. To analyze any effect on diffusion, we adopt a difference-in-differences estimation, comparing the number of forward citations received by patents pledged to the EcoPC before and after they were pledged to citations received by the set of matched control patents that were not pledged to the EcoPC. Our estimation approach allows for different citation patterns between the set of EcoPC and control patents before the EcoPC patents were pledged. This accounts for concerns that pre-pledge citation behavior could be correlated with the decision to pledge a given patent to the EcoPC.

Table 5 shows a comparison of standard patent characteristics between the set of patents pledged to the EcoPC and the matched (by priority year, IPC subclass, and publication authority) control patents where we focus on the priority patents (Table A-1 in the appendix shows the data for all equivalents). There are no statistically significant differences between the grant lag, the number of backward or non-patent literature references between the two sets of patents. Interestingly, EcoPC patents are more likely to be pursued until grant. However, control patents have a larger family size and a larger number of claims both of which are commonly used patent value indicators. This suggests that the EcoPC patents potentially are of less value than otherwise comparable patents. When we look at the number of forward citations received, the set of control patents accumulated a larger average number of citations than the pledged patents.

Table 5

Mean patent characteristics for 89 Eco-patents and 90 control patents#

Variable	*Controls*	*Ecopatents*	*Difference (s.e.)*	*p-value*	*Kruskal-Wallis test*	*p-value*
Application year	1998.9	1998.8	-0.10 (0.68)	0.882	0.01	0.920
D (granted)	0.51	0.73	0.22 (0.07)	0.002	6.42	0.011
Grant lag in years*	3.93	3.74	-0.19 (0.55)	0.725	1.25	0.264
Family size	5.24	3.78	-1.47 (0.62)	0.018	4.54	0.033
Number of claims*	23.61	14.60	-9.01 (3.87)	0.023	2.88	0.090
Forward patent cites	22.67	13.22	-9.44 (4.04)	0.021	2.25	0.134
Backward patent cites	7.39	5.63	-1.76 (2.07)	0.397	1.74	0.187
Non-patent references	2.50	1.10	-1.40 (1.33)	0.294	0.02	0.903
Number of applicants	1.10	1.04	-0.06 (0.09)	0.553	0.02	0.899
Number of inventors*	2.70	3.00	0.30 (0.28)	0.294	2.12	0.145

A few control observations (5 in total) were lost due to missing data.

* The mean is shown for non-missing observations only.

The Kruskal-Wallis test is a rank test for the equality of the two populations.

Table 6 below shows the share of EcoPC and control patents that receive any citations as well as the average number of citations received (Table A-2 in the appendix shows a comparison of patent characteristics for patents with non-zero forward citations). As indicated earlier, compared to Table 6 in Hall and Helmers (2013), there are slightly fewer equivalents of our EcoPC patents and controls due to missing data and the consolidation at the APO. The share of patents that have citations has increased, becoming close to 90 per cent for the equivalence groups, and the average citations per equivalence group has more than doubled. None of these results are unexpected, given the additional five years of data, as well as probable improvements in the PATSTAT coverage itself, but also highlights our much improved ability to assess the question of technology diffusion as a result of the EcoPC.

Table 6: Citation counts for EcoPC patents and controls

	all patents	*equivalence group*	*all patents*	*equivalence group*	*all patents*
	Total patents		*Share with citations*		*Total citations*
Eco-patents	237	90	73.0%	85.6%	1343
Controls	461	94	57.1%	93.6%	2713

	*Average citations**		*Average citations***	
Eco-patents	10.5	17.4	5.7	14.9
Controls	13.2	30.8	5.9	28.9

Citations are measured as all forward citations in the patent literature between the application date and April/May 2017, adjusted for citations by equivalent patents in other jurisdictions.

*Average over patents with nonzero citations.

**Average over all patents

Table 7 and Figure 3 below show the key results of our new analysis. Poisson and negative binomial models of citations at the patent-level show that EcoPC patents are half as likely to be cited than the controls (an elasticity of 0.4-0.6), and even less likely after donation, although this last result is only marginally significant. These regressions control for both priority year and the citation lag using dummies.

It is well-known that the citation lag distribution for patents has a somewhat smooth structure, rising at first to a peak at 3-5 years and then declining slowly. We therefore attempt to improve the precision of our estimates by imposing the Jaffe-Trajtenberg model of citation diffusion and decline (Jaffe and Trajtenberg, 1999) rather than using the citation lag dummies. This model, shown in the final three columns of Table 7, uses a parametric model for the citation lag that is given by the following equation:

$$c_{st} = \beta_0(1 + \delta_{eco} D_{eco} + \delta_{after} D_{after}) f(t) \exp[-\beta_1(1 + \beta_{1e} D_{eco}) s][1 - \exp(\beta_2(1 + \beta_{2e} D_{eco})\mathrm{s})] + \varepsilon_{st}$$

Where *t* is the priority year of the cited patent, *s* is the citation lag, and c_{st} is the citation rate (the number of citations at that lag per sample patents available to be cited). *f(t)* is modeled as a set of priority year dummies. That is, the unit of observation is the average cites per patents with a given priority year, citation lag, and patent type (EcoPC patent before and after or control). Prior experience with this specification suggests that although it is an appealing model in that it captures both the initial increase in citation due to knowledge diffusion and the decline due to knowledge age, it is quite difficult to estimate successfully (Hall et al. 2001). We do it in two ways: (1) nonlinear least squares with a dependent variable equal to average cites per patent, and (2) Poisson with a dependent variable equal to the total cites at the given lag to patents with a given priority year. In the latter case we multiply the right hand side of the model by the number of patents, so the models are equivalent. The results from the two estimation strategies are similar. Once we impose a model on the citation lag, the EcoPC patents are cited an average of 25 per cent less than the controls, and there is no change after donation. The decay (obsolescence) and diffusion parameters are similar to those obtained by Hall et al. (2001) for the US patent data, with obsolescence increasing by about 5 per cent per year, and diffusion about 50 per cent. However, keep in mind that one reason the first is relatively low and the second relatively high is that there is a secular growth in citations that is not completely captured by the priority year dummies. That is, this model imposes a fixed citation lag structure on the data which is then allowed to be higher or lower, depending on priority year and EcoPC status. Because citations are often added by examiners rather than applicants,[28] we also report results in Appendix Table A-3 and Figure B-1 where we retain only citations made by applicants. That said, the results are very similar to the ones reported in Table 7 and Figure 3; there is no evidence of increased diffusion of patents after they were pledged to the EcoPC.

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[28] Note that for the purposes of analyzing diffusion, it is preferable to include citations added by examiners because these citations also indicate that the citing patent builds on the cited prior art where this relationship was identified by examiners who are commonly experts in the relevant technology areas.

Table 7: Estimation of citation lag models

Model	*Semi-parametric*						*Jaffe-Trajtenberg*								
Dependent variable	*Cites*			*Cites*			*Cites/patent*			*Cites*			*Cites*		
Method	*Poisson*			*Negative binomial*			*NLLS*			*Poisson*			*Poisson*		
EcoPC patent	-0.60	(0.11)	***	-0.42	(0.10)	***	-0.33	(0.09)	***	-0.22	(0.04)	***	-0.25	(0.05)	***
EcoPC patent after donation	-0.35	(0.21)		-0.33	(0.17)	*	-0.10	(0.18)		-0.01	(0.08)		0.01	(0.08)	
Decay parameter							0.07	(0.02)	***	0.04	(0.01)	***	0.05	(0.01)	***
Diffusion parameter							0.49	(0.21)	**	0.76	(0.19)	***	0.64	(0.21)	***
EcoPC decay													0.47	(0.38)	
Dispersion parameter				3.21	(0.17)	***									
Citation lag dummies	yes			yes			no			no			no		
Priority year dummies	yes			yes			yes			yes			yes		
Observations	3071			3071			518			518			518		
Log likelihood	-6,143.0			-3,745.2			-845.6			12,062.8			12068.6		

Sample: 94 controls and 90 EcoPC patents with priority years between 1992 and 2005 and citing years between 1992 and 2016. The unit of observation in the first two columns is a priority patent-citing year and in the next three columns a priority year-citing year.

Standard errors are robust to heteroskedasticity.

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

Figure 3

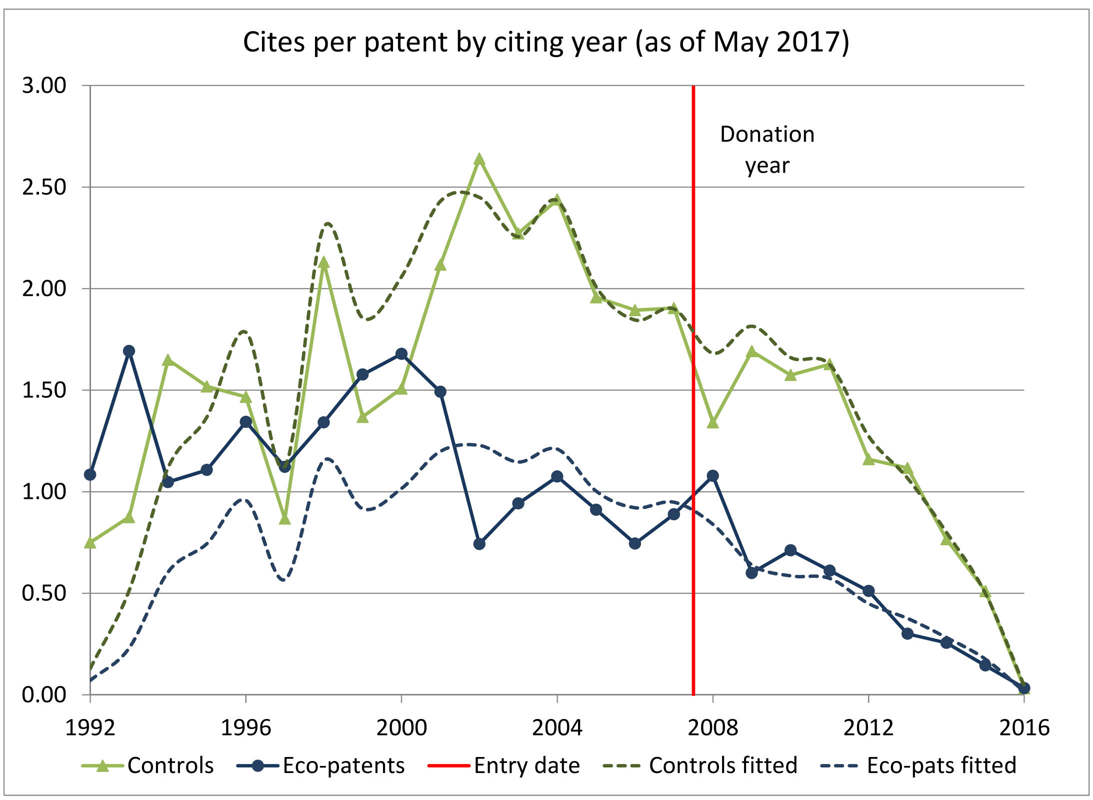

Table 7 and Figure 3 show that there is little change in aggregate citation differences between EcoPC patents and controls before and after being pledged to the commons, although EcoPC patents are cited less overall. It is important to remember, however, that because the pledging firms retain a defensive termination right, there may be continuing innovation building on these patents that does not result in new patent applications (and citations). That is, there are limits created on the enforcement of patent rights by the firms that use the technologies in these patents, which may reduce the benefits of subsequent patenting, and thus reduce citations to the pledged patent. This issue is related to a broader problem: our analysis of diffusion only looks for diffusion that leads to follow-on innovation that is patented. This excludes simple use of pledged patented technologies and even follow-on innovation if it does not lead to a patent filing. However, in the absence of any information on the use of pledged patents (see Section 3 above), the forward citation analysis is the only way to quantitatively assess the impact of the patent pledge on diffusion.

It is also possible that the nature of the citation changes, in that the technology in the patents becomes more useful to individuals and non-profit institutions given the absence of royalty requirements. We investigate this question by looking at the source of the citations to the EcoPC patents and controls before and after donation. We divide the cites into five groupings according to their source: self-citations from the firm that owns the pledged patent, citations from other EcoPC participants, citations from other firms, citations from individual patentees, and citations from non-profit institutions (universities, hospitals, public research organizations (PROs), and governments). We then define the before and after period for each grouping of citations according to the relation between the earliest priority date for the citing patent and the date the cited patent was donated to the commons. The results are shown in Table 8. In some cases, sample sizes are fairly small, but it does appear that self-citation falls relative to all the other categories, with the largest (percentage) increases in citations by other EcoPC participants and non-profit institutions.

One issue that arises when counting the source of citations is that many patents have multiple applicants of different types. Given the nonrivalry of knowledge, which implies that one citer's use of the knowledge in a patent does not depend on use by another citer, it might be appropriate to simply count all the applicant-citations as citations as we did in the first panel of Table 8. Nevertheless we also show a weighted version of the table in the second panel where the weights are proportional to the inverse of the number of applicants on the citing patent.[29] Although the distribution of cites changes dramatically when we weight, due to the tendency of individuals to share in applications, the qualitative conclusions with respect to the post-commons citing behavior are the same.

[29] We removed individual inventor-applicants where there was also a firm applicant before computing the weights, on the grounds that these applicants usually are employed by the firm in question.

As described earlier, in order to validate our quantitative results, we asked the inventors of patents that cited an EcoPC patent after they were pledged (a) whether they were aware of the citation (we exclude citations added by examiners), (b) if they were aware of the citation, whether they knew that the cited patent was part of the EcoPC, and (c) if they had answered (a) and (b) affirmatively, whether the fact that the EcoPC patent was available for use royalty-free played any role in their decision to rely on it as prior art. As explained in Section 4 above, we obtained valid responses from 10 inventors; 50% indicated that they were aware of the citation, but none of them was aware that the cited patent was part of the EcoPC. While the sample of inventors is obviously very small, it nevertheless confirms our quantitative results: the pledge of a patent to the EcoPC was ineffective in spurring the diffusion of the patented invention. In fact, the responses from the inventors also confirm the results of our interviews with company representatives as they suggest that inventors were unware of the EcoPC even when they relied on patents that were part of the EcoPC as prior art.

Table 8

Citation to the eco-patents by citer type

	Unweighted				*Weighted*			
Firm	*Before donation*	*After donation*	*Share before*	*Share after*	*Before donation*	*After donation*	*Share before*	*Share after*
Self-citation	141	24	9.9%	4.6%	127.1	12.9	12.3%	3.9%
Other eco-patent	11	13	0.8%	2.5%	8.0	7.3	0.8%	2.2%
Other firm	645	248	45.1%	47.1%	627.5	229.8	60.5%	68.8%
Individual	589	219	41.2%	41.6%	243.0	71.7	23.4%	21.5%
Institution	43	22	3.0%	4.2%	31.7	12.4	3.1%	3.7%
Total	**1429**	**526**			**1037.3**	**334.1**		

These totals are for cites to the contributed eco-patents only.

Weighted cites are weighted according to the number of applicants.

6. Conclusion

The results of our empirical analysis suggest fairly strongly that the technologies covered by the contributed patents did not in fact attract a lot of interest by third parties, even before contribution to the commons. As a result, pledging these patents to the commons did not affect the interest of third parties in their underlying technologies and hence the commons did not promote their use and diffusion.

One of the reasons for the EcoPC's lack of effectiveness is the fact that it was conceived and implemented by the suppliers of technology as a volunteer effort without consulting the demand side (potential users of these patents/technologies). As such, the EcoPC was constructed in such a way that it was not easy for potential users to understand how the available technologies could be used. It simply offered a passive web site with patent listings, rather than suggestions how these technologies could be utilized, either separately or together.[30] Our results suggest that effective technology diffusion requires more than patent non-assertion, especially in the developing world. Technical assistance and know-how are essential for implementing environmental technologies to an even greater degree than for software or pharma (Barton et al., 2002; McManis and Contreras, 2014) and patent disclosures alone are seldom sufficient to enable someone to implement a technology effectively (see Ouellette, 2012 for the results of a survey of patent readers).

Likewise, there was little or no coordination among EcoPC contributors regarding the technologies covered by the patents they were contributing. As discussed in Hall and Helmers (2013), the pledged patents appeared to largely protect different technologies. Hence, the implementation of a given technology might not have been possible using only pledged patents (i.e., any of the covered technologies could require the use of additional patents not contributed to the commons). As a result, synergies that could have emerged from the contribution of multiple patents covering selected technologies did not emerge.

Perhaps the most cogent critique of the EcoPC was its lack of tracking of patent utilization. Without knowledge of how/whether patents were being utilized, companies could not justify expending further effort on the activity. Moreover, even the public relations benefit of belonging to the EcoPC waned after the initial contributions, given that there were no 'success stories' to promote. More generally, the lack of information on usage meant that it was very difficult to gauge the success of the initiative and to make adjustments to its structure and management to improve its performance. Finally, the lack of demonstrable results from the project eroded the potential public relations benefits that member firms may have hoped to achieve from participation in the EcoPC.

This lack of usage tracking underscores another weakness of the EcoPC, especially when compared to more successful pledge communities: the lack of dedicated administrative and managerial resources devoted to expanding and promoting the commons. While EcoPC was housed within well-established organizations such as WBCSD and ELI, these organizations received no additional compensation for managing EcoPC and appear to have taken on this role as an accommodation to a significant member (IBM). As the example of DPL has shown (Contreras 2018), the lack of dedicated managerial and promotional resources can contribute to the failure of a pledge community to gain significant traction in the marketplace.

[30] A similar supply-side model for patents can be found in the IPXI Exchange, an attempt to offer unitized licenses of pooled patents essential to certain industry standards. Like the EcoPC, IPXI failed to achieve significant take-up and eventually discontinued its operations (see Contreras, 2016).

The experience of the EcoPC, even though it did not realize its ambitious goals, has helped to advance our understanding of how patent commons can work and fail to work. As such, the EcoPC has made an undeniable contribution to the study of patent commons and pledges.

References

Abud, M. J., C. Fink, B. H. Hall, and C. Helmers (2013). The use of intellectual property in Chile. INAPI-WIPO Report, Economic Research Working Paper No. 11 (July).

Awad, B. (2015). Global patent pledges: a collaborative mechanism for climate change technology, CIGI Papers No. 81, https://www.cigionline.org/sites/default/files/no.81.pdf.

Barton, John, et al. (2002). Integrating Intellectual Property Rights and Development Policy, Report of the UK Commission on Intellectual Property Rights. Available at http://www.iprcommission.org/papers/pdfs/final_report/ciprfullfinal.pdf

Belenzon, S. (2006). Knowledge Flow and Sequential Innovation: Implications for Technology Diffusion, R&D and Market Value. Available at SSRN: https://ssrn.com/abstract=893060 or http://dx.doi.org/10.2139/ssrn.893060

Bowman, J. (2009). The Eco-Patent Commons: Caring Through Sharing, *WIPOMAG*., June 2009.

Contreras, J.L. (2018). The Evolving Patent Pledge Landscape, CIGI Papers No. 166, Apr. 3, 2018, https://www.cigionline.org/publications/evolving-patent-pledge-landscape

----- (2016). FRAND Market Failure: IPXI's Standards-Essential Patent License Exchange, *Chicago-Kent J. Intell. Prop*. 15(2): 419-440.

----- (2015). Patent Pledges. *Arizona State L.J*. 47(3): 543-608.

----- (2014). Constructing the Genome Commons in *Governing Knowledge Commons* at Ch. 4 (M. Madison, K. Strandburg & B. Frischmann, eds., Oxford Univ. Press).

Contreras, J.L., B.H. Hall, C. Helmers (2018). Assessing the Effectiveness of the Eco-Patent Commons: A Post-mortem Analysis. CIGI Paper No. 161. Available at https://www.cigionline.org/publications/assessing-effectiveness-eco-patent-commons-post-mortem-analysis

Crouch, D. (2012). IBM's Patent Abandonment Strategy. *Patently-O Blog* (Mar. 1, 2012), https://patentlyo.com/patent/2012/03/ibms-patent-abandonment-strategy.html .

Eco-Patent Commons (2013a). Joining or Submitting Additional Patents to the Commons, currently available at https://ecopatentcommons.org/sites/default/files/docs/ecopatentgroundrules.pdf (accessed Aug. 19, 2017).

----- (2013b). The Eco-Patent Commons: A Leadership Opportunity for Global Business to Protect the Planet,

----- (2016). Important Statement from the Board: Eco-Patent Commons to Cease Active Operations Effective May 18, 2016, https://ecopatentcommons.org/ (accessed Aug. 19, 2017).

----- (2017). About the Eco-Patent Commons, https://ecopatentcommons.org/about-eco-patent-commons (accessed Aug. 19, 2017).

Hall, B.H. and C. Helmers (2018). The Impact of International Patent Systems: Evidence from Accession to the European Patent Convention, NBER Working Paper 24207.

----- (2013). Innovation and diffusion of clean/green technology: Can patent commons help? *Journal of Environmental Economics and Management* 66(1): 33-51. *doi:10.1016/j.jeem.2012.12.008*

----- (2010). The role of patent protection in (clean/green) technology transfer, NBER Working Paper No. 16323.

Hall, B. H., A. Jaffe, and M. Trajtenberg (2001). The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools. Cambridge, MA: NBER Working Paper No. 8498.

IBM News Room (2008). Corporations go Public with Eco-Friendly Patents (Jan. 14, 2008).

IBM (2010). *IBM and the Environment: 2009 Annual Report*.

Jaffe, A. and M. Trajtenberg (1999). International knowledge flows: evidence from patent citations, *Economics of Innovation and New Technology* 8: 105-136.

LOT Network. (2018). The LOT Network Community, <http://lotnet.com/our-community/#member-list>

Mattioli, M. (2012). Communities of Innovation. *Northwestern Univ. L. Rev*. 106(1):103-155.

McManis, C.R., and J.L. Contreras (2014). Compulsory Licensing of Intellectual Property: A Viable Policy Lever for Promoting Access to Critical Technologies?, in Ghidini, G., R.J.R. Peritz, and M. Ricolfi, eds. *TRIPS and Developing Countries – Towards a New IP World Order?* (Edward Elgar).

Merges, R.P. (2004). A New Dynamism in the Public Domain, *Univ. Chicago L. Rev*. 71:183-203.

Ouellette, Lisa L. (2012). Do patents disclose useful information? *Harvard Journal of Law & Technology* 25 (2): 545-603

Reynolds, J.L, J.L. Contreras, and J.D. Sarnoff (2017). Solar Climate Engineering and Intellectual Property: Toward a Research Commons. *Minnesota J. Law, Science & Tech.* 18(1): 1-110.

Sarnoff, J.D., ed. (2016). *Research Handbook on Intellectual Property and Climate Change* (Edward Elgar).

Tripsas, M. (2009). Everybody in the Pool of Green Innovation. *NY Times* (Nov. 1, 2009).

Van Hoorebeek, M. and Onzivu, W. (2010). The Eco-Patent Commons and Environmental Technology Transfer: Implications for Efforts to Tackle Climate Change. Climate Change L. & Reg. 2010(1): 13-29.

Wen, W., M. Ceccagnoli, C. Forman (2013). Patent Commons, Thickets, and Open Source Software Entry by Start-Up Firms. Cambridge, MA: NBER Working Paper 19394, http://www.nber.org/papers/w19394.pdf .

Online appendix (not for publication)

Appendix A: Additional tables

Table A-1

Mean patent characteristics for 236 Eco-patents and 454 control patents

Variable	*Controls*	*Ecopatents*	*Difference (s.e.)*	*p-value*	*Kruskal-Wallis test*	*p-value*
Application year	1998.8	1997.8	-1.02 (0.39)	0.009	5.65	0.017
D (granted)	0.51	0.68	0.17 (0.04)	0.000	13.30	0.000
Grant lag in years*	4.63	4.14	-0.49 (0.30)	0.103	4.32	0.038
Family size	8.83	5.96	-2.87 (0.40)	0.000	43.19	0.000
Number of claims*	23.05	14.90	-8.15 (2.41)	0.000	9.63	0.000
Forward patent cites	27.24	15.92	-11.32 (2.28)	0.000	17.28	0.000
Backward patent cites	5.96	4.31	-1.65 (1.19)	0.167	8.49	0.004
Non-patent references	1.32	0.66	-0.66 (0.44)	0.136	0.10	0.758
Number of applicants	1.13	1.11	-0.02 (0.07)	0.765	0.18	0.673
Number of inventors*	2.83	2.91	0.07 (0.17)	0.675	3.61	0.057

* The mean is shown for non-missing observations only.

The Kruskal-Wallis test is a rank test for the equality of the two populations.

Table A-2

Patents with nonzero forward cites only (437 controls; 218 eco-patents)

Variable	*Controls*	*Ecopatents*	*Difference (s.e.)*	*p-value*	*Kruskal-Wallis test*	*p-value*
Application year	1998.7	1997.6	-1.14 (0.40)	0.004	7.13	0.008
D (granted)	0.51	0.70	0.19 (0.04)	0.000	15.23	0.000
Grant lag in years*	4.60	4.14	-0.46 (0.31)	0.131	3.29	0.070
Family size	9.03	6.26	-2.78 (0.41)	0.000	37.56	0.000
Number of claims*	23.23	15.11	-8.11 (2.45)	0.001	9.17	0.003
Forward patent cites	28.30	17.23	-11.07 (0.38)	0.000	13.05	0.000
Backward patent cites	6.11	4.57	-1.53 (1.26)	0.223	9.23	0.002
Non-patent references	1.36	0.70	-0.66 (0.47)	0.161	0.19	0.665
Number of applicants	1.12	1.11	-0.01 (0.07)	0.844	0.21	0.649
Number of inventors*	2.82	2.97	0.14 (0.18)	0.425	6.36	0.012

* The mean is shown for non-missing observations only.

The Kruskal-Wallis test is a rank test for the equality of the two populations.

Table A-3

Applicant cites only

Model	*Semi-parametric*						*Jaffe-Trajtenberg*						
Dependent Variable	*Cites*			*Cites*			*Cites/Patent*			*Cites*			*Cites*
Method	*Poisson*			*Negative Binomial*			*NLLS*			*Poisson*			*Poisson*
EcoPC Patent	-0.87	(0.15)	***	-0.65	(0.13)	***	-0.65	(0.05)	***	-0.45	(0.08)	***	NOT
EcoPC Patent after donation	-0.64	(0.29)	**	-0.51	(0.22)	**	--			--			IDENTIFIED
Decay Parameter							0.05	(0.68)		0.09	(0.02)	***	
Diffusion Parameter							0.13	(0.28)		0.10	(0.01)	***	
EcoPC Decay													
Dispersion Parameter				4.47	(0.35)	***							
Citations Lag Dummies	yes			yes			no			no			no
Priority Year Dummies	yes			yes			yes			yes			yes
Observations	3046			3046			512			512			512
Log Likelihood	-3,422.0			-2,212.4			-588.6			3,566.6			

Sample: 94 controls and 90 EcoPC patents with priority years between 1992 and 2005 and citing years between 1994 and 2016. The unit of observation in the first two columns is a priority patent-citing year and in the next three columns a priority year-citing year.

Standard errors are robust to heteroskedasticity.

Significant at the one per cent (***), five per cent (**) and 10 per cent (*) levels.

Appendix B: Additional figure

Figure B-1