A Forward Patent Citation Study of Patented Oil and Gas Technologies with Environmental Applications

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ABSTRACT: The proper dissemination of current environmental technology may result in significant advancements in environmental impact reduction. The dissemination of information linked to environmental technology produced within the oil and gas sector is examined in this study. We use forward patent citations technique to evaluate knowledge spillovers from oil and gas innovations as a measure of technology diffusion. The findings indicate that if the original oil and gas innovation has already been connected to environmental technologies, the cited patent is very likely to be linked to environmental technologies in the future. Furthermore, both intra and intersect oral spillovers result in a "turnaround" effect, in which citing patents have the opposite quality level as the cited patent. Our findings support the hypothesis that stronger sector-specific environmental regulations, with a focus on diffusion, would substantially enhance the adoption of environmental technology produced in the oil and gas industry.

KEYWORDS: Patent, Petroleum Industry, Environmental, Innovations, Technology.

1. INTRODUCTION

Since its inception, the petroleum1 sector has unquestionably contributed to global economic development, wealth creation, increased affluence, and pushed many nations' living standards higher. Renewable energy has remained important to the energy business despite significant penetration in recent years. Furthermore, despite its ongoing crises, it is anticipated that it will continue to play this function for some time. For example, the sector meets almost all of the world's transportation energy needs and provides a huge supply of raw materials for chemical goods and processes. During the twentieth and twenty-first centuries, the oil shocks of the 1970s were the only interruptions to an otherwise unbroken production trend. According to the International Energy Agency's cautious forecast for 2035, increased demand from emerging nations will maintain the production trend up. Externalities are unexpected good or bad effects on other economic and social actors that are not captured by the pricing system, as they are with much other economic activity.

In this regard, certain oil and gas energy sources have significant negative environmental consequences. For example, greenhouse gases (GHG) emissions and other forms of pollution Department of Public Economics and Chair on Energy and Environmental Sustainability, University of Barcelona, Barcelona Institute of Economics, Av. Diagonal 690, 08034 Barcelona, Spain. The burning of fossil fuels produces pollutants. Oil spills and other refining by-products that end up in lakes, rivers, and the sea contribute significantly to water pollution. Environmental regulations are required to remedy these market failures by balancing the marginal costs and benefits of environmental preservation. Carbon capture and sequestration (CCS) and flue-gas desulfurization (FGD) are two of the most well-known technologies for reducing CO_2 and SO_2 emissions, respectively [1]. Technology may be used to lower the cost per unit of energy or to decrease the amount of energy required to carry out tasks, thus increasing wellbeing. Environmental policies, promote technological change towards so-called clean technology through altering relative pricing. These are technologies that are designed to provide the same quantity of products and/or services while causing less environmental damage.

The use of various policy tools, which are often divided into two categories: market-based instruments (MBI) and command and control instruments, results in a shift in relative pricing (CAC). The latter refers to regulations that limit the amount of pollution that any agent may produce. The former used a variety of methods, including taxes, tradable pollution permits, and fees[2], to establish explicit markets for negative environmental externalities. Technology policy may also be used to address the mitigation of these negative environmental impacts caused by the petroleum sector and associated activities. In this scenario, R&D subsidies for clean technology, for example, may be intended to encourage complementing private investment in the development of new innovations or improvements to existing ones that reduce the negative environmental effects of human activities.

The presence of two distinct kinds of externalities justifies both environmental and technological regulations, a scenario known as the "double externality issue" The argument for environmental policy stems from the reality that without the right incentives, agents will not be able to reap the benefits of their efforts to preserve the environment, resulting in pollution levels that are higher than they should be. The appropriability argument states that once the information supporting a new technique or invention is revealed, it is accessible to other agents to duplicate it, reducing the rewards to the creator and creating a suboptimal level of R&D expenditure [3]. These points demonstrate that technology is inextricably connected to energy and the environment. Energy, environmental, and technological policies are all strategically intertwined in this regard, and each must be developed with the others in mind to maximize their efficacy. Environmental policy is believed to promote eco-innovations through encouraging the development of new clean technologies. There is a significant body of research on the importance of environmental policy in promoting the development of new technology via innovation. However, another approach would be to recognize that significant improvements in environmental effect mitigation may also be achieved via the proper dissemination of current environmental technology .New technology diffusion is understood to be a slow process.there are two possible explanations for this trend. On the one hand, the new technology's anticipated value will vary depending on the diversity of prospective users [4].

When users are very diverse, the adoption rate of a new technology is often low, at least in the early phases of its development.Adoption of new technology, on the other hand, entails an unknown level of risk. Prior to acceptance, information on the new technology's important features would have to be widely disseminated. Carraro et al. (2010) also contend that uncertainty plays a role in the sluggish pace of technology diffusion equation. When agents see a high pace of innovation, they anticipate a high rate of technical obsolescence and will be hesitant to embrace the technology. These writers also claim that there is adequate evidence to support the idea that environmental legislation may help foster innovation and the spread of new environmentally friendly technology. We'll look at how information about environmental technology created in the oil and gas sector is spreading. In this paper, we examine the spread of copyrighted oil and gas technologies, with a particular emphasis on the claimed environmental benefits of these innovations. Given that the petroleum industry is responsible for a significant portion of the negative impact on the global environment, understanding how far technologies developed in this sector embrace environmentally friendly uses is critical for the development of future energy and environmental policies, as well as informing international climate change negotiations. The following is a breakdown of the paper's structure.

Detail the data, highlight the benefits and disadvantages of using patents as a measure of technical innovations, and explain how to monitor technological spread using citations. We also provide the empirical technique to be utilized in the oil and gas industry's examination of forward patent citations. The policy component is given special attention in this section. The dataset used to analyze the spread of patented oil and gas technology is described in this part, followed by a discussion of the benefits and disadvantages of patents as markers of innovation. The data is also subjected to an explanatory and descriptive analysis. Finally, we describe the methods we use for the empirical study of forward citations, which include a count data model for determining citation counts and a multilevel model for capturing the features of both the citing and cited patents [5].

2. DISCUSSION

The goal of this study is to look at how patented oil and gas technology are spreading. Although many indicators are available, we will concentrate on forward patent citations to assess the amount of knowledge spillovers resulting from oil and gas innovations. Citation mappings from one patent to another are seen to be useful – although imperfect – knowledge flow mappings .For the study of the connections between technology and the environment, patent data has a number of appealing characteristics. The technical breakdown for which patents are accessible, for example, is very comprehensive, making them a good indication for technology creation and dissemination study.Furthermore, patents incorporate references to prior innovations, since patent applicants are obliged to provide references to prior patents that were utilized to create the novel technology or knowledge stated in the patent. As a result, they are a kind of knowledge and/or technology flow. There are, nevertheless, certain considerations to be made. Because not all innovations are registered, patent citations may understate the true quantity of information spillovers. 268 N. Finally, patent examiners may introduce bias into knowledge spillover metrics by adding citations throughout the assessment process. Despite these disagreements, as well as additional concerns about quality, strategic behavior, and geographic agglomeration of knowledge, there is some agreement in the literature on the economics of innovation that patents are good indicators of the output of innovation efforts [6].

Citations to earlier patents, in particular, indicate the impact of a patented invention on subsequent developments. The trial of knowledge flows in many dimensions may then be followed using citations (time, technologies, geographies, institutions). Numerous contributions have proven the validity of patent citations as a measure of technology dissemination since Trajtenberg's pioneering work in 1990 instance, shown that citations are acceptable representations of information flows, even when they include significant noise. In the energy industry, the literature on patent analysis has shrunk to only a few articles .Data from the World Patent Statistical Database is used to examine the spread of oil and gas technology European Patent Office (EPO) created and secures this database, which contains approximately 70 million patent papers from more than 100 patent offices across the globe and is the world's biggest patent repository. Other sources of patent information include the United States Patent and Trademark Office (USPTO), which has approximately 11 million patent papers, and other national patent offices, which have considerably less information. The Derwent World Patent Index (DWPI) is a global database that contains patent applications from 44 different patent offices and information on 45 million documents. The DWPI categorization method is used to identify patents in the oil and gas industry. The term "petroleum" refers to all elements of the oil and gas business, and class H covers them all. It also finds the appropriate International Patent Classification (IPC) codes to characterize the PATSTAT database data. The International Patent Classification System (IPC) is a standard developed by the World Intellectual Property Organization that is used to categorize patents consistently in over 100 nations (WIPO). The USPTO and the EPO have established a new categorization method, the Cooperative Patent Classification System (CPC) that seems to better identify the various technologies. However, it was just approved by the EPO in 2013, and it will come into effect at the USPTO in 2015; it is the product of a bilateral (rather than international) agreement, and no other nations have embraced it save China (in 2014).

According to the DWPI, displays the number of applications, families, and citations retrieved from the database and related to the petroleum industry. Patents may be issued in several countries for the same innovation. We concentrate on patent families to prevent duplicate counting of citations to the same fundamental innovation. This involves counting citations at the family level rather than at the individual patent level, and considering numerous patent applications as one innovation. In all, 389,607 patent applications were filed between 1990 and 2010, representing 190,284 innovations (families). The graph depicts a well-known rise in the number of patent applications (and families) beginning in the second half of the 1990s, as well as a strong connection with oil and gas R&D spending. To what degree this might be the industry's reaction to the Kyoto Protocol's acceptance by many nations is a different research issue, although the statistics clearly indicate some timing coincidence[7].

2.1. Application:

Using two distinct methods, we will evaluate the presence and significance of knowledge spillovers from patented oil and gas technology. To begin, we'll use citation counts to determine whether or not intersect oral knowledge spillovers occur and are significant. Second, we'll utilize the features of the referencing patents to supplement the data on knowledge dissemination patterns obtained from patented oil and gas technology. One of the main goals, as stated in earlier sections, will be to investigate the connections between these patent families and environmental technology. In order to clean the estimates from as many potential confounding factors as possible, we include a number of control variables in Xi. First, differences in patent office practices across time and technological areas may produce artificial differences in citations intensities. We therefore include a full range of patent office and sector fixed effects. Second, the mean count of citations received and made evolve over time. Specifically, there is a problem related to those patents filed in recent years since the time they have been exposed to citations is considerably shorter than for patents filed in the early years of our sample. Hence, a full collection of time effects (filing year) is also included.

Finally, we also control for the type of applicant (individual, company, government, university) by including type of applicant fixed effects since their patenting strategies could also differ. This allows us to effectively compare exclusive and/or environmentally related oil and gas patents filed for instance in the EPO in 2000 with inclusive patents – or patents not related to environmental technologies – filed at the EPO the same year. As we discussed in the previous section, citations can also reflect the intrinsic quality of the patent instead of knowledge flows[8]. To control for this issue we include two widely accepted measures of patent quality. First, we use the patent family size reflecting the number of different patent offices where the same invention has been filed. Second, we use the grant status of the invention indicating if the patent has been granted by the patent office[9].

2.2. Advantage:

Clean technologies have an obvious disadvantage since filthy technologies have a larger installed base. More active governmental action is required to support the rapid development – and particularly spread of clean technology. Patent licensing, for example, may be a key component in the development of clean technology policy, especially in the energy sector. The creation of environmental standards, eco-taxes, tradable licenses, and investment subsidies are other policy tools ideally adapted to dealing with technology spread. Instruments such as ecolabels and network management are particularly important since they address the information externalities of dissemination.

If a technology has already been created, only government intervention can increase the pace of dissemination beyond what the market can offer. There is a matching issue in the mitigation of environmental hazards. On the one hand, high-income nations create the most appropriate clean technologies. However, emissions are increasing at a faster rate in the developing countries. As a result, future governments will need to consider the possible role of international technology transfer schemes as incentive-based mechanisms for promoting clean technology dissemination at a global scale. Improving absorptive capacity or facilitating trade access, according to Popp (2012), may be a low-cost approach to increase spillovers. To begin with, actions aimed at improving a country's absorptive capacity improve the possibility for benefitting from knowledge spillovers.

2.3. Working:

We identify the key features of the citing patent to control for the observed characteristics of the technology employing oil and gas original innovations, as stated in the previous subsection. We construct four dependent variables to capture the many applications of oil and gas technical knowledge, allowing us to examine the possible knowledge spillovers resulting from these patented innovations. The IPC code(s) contained in the patents that reference those initial innovations are used to describe the knowledge included in the original oil and gas patent applications. The dependent variables are: I OUTER, which is equal to 1 if the citing patent exclusively includes nonoil and gas IPC codes and 0 otherwise; (ii) MIXED, which is equal to 1 if the citing patent includes both outer and oil and gas codes and 0 otherwise; (iii) INNER, which is equal to 1 if the citing patent exclusively includes oil and gas IPC codes and 0 otherwise; and (iv) ENVIRONMENTAL, These three variables represent the degree to which knowledge gained in the oil and gas business spreads to other industries, especially to environmental innovations. For example, if the IPC codes of the cited patents do not contain oil and gas ones), we will assume that the original oil and gas innovation was utilized for “outer” uses. Intersectorial spillovers are one example of this. In a similar vein, if the cited patents' IPC codes contain other codes in addition to oil and gas codes, we consider the oil and gas original invention to have been utilized for mixed purposes, resulting in "shared" spillovers. Finally, if one of these patents only contains IPC codes for oil and gas, we may argue that the information contained in the reference oil and gas innovation has only been used for “inner” purposes. Spillovers in this instance are of an intraindustry character. As previously stated, one unique and fascinating situation occurs in interindustry spillovers when the citing (or referenced, or both) patents include environmental technology links.

The independent variables may be split into two groups using this structure. The first relates to elements that reflect the cited document's qualities. The second includes indications that represent the original invention's characteristics. The next sections will focus on the quality of both citing and cited patents. We continue to depend on the two quality-proxying factors of family size and granted status. In addition, as in the previous sub-section, we incorporate separate effects for patent office, application year, sector, and kind of applicant to account for as many confounders as feasible.Two factors influence which econometric technique should be utilized. First, we created four binary dependent variables based on the application of oil and gas technology (outer, mixed, or inner uses, and environmental) in order to capture important spillovers. Second, and more crucially, there are two kinds of explanatory variables. On the one hand, we have variables that represent the cited patents' features. However, we must also examine the characteristics of the original oil and gas innovation. Because several referencing patents are connected to the same originating patent, the values of these explanatory variables are repeated in this final instance. From the standpoint of forward patent citation analysis, these reasons indicate that the multilevel logit model is the most appropriate econometric estimate technique for analyzing the applications of patented oil and gas technologies.

3. CONCLUSION

Because the bulk of this information stays inside the business, the findings presented in the preceding sections demonstrate, first, that there are no significant knowledge externalities generated from copyrighted oil and gas technologies. Importantly, environmental patents in the oil and gas industry make up a small percentage of total applications and get fewer citations than either inclusive or exclusive patents in other areas. Second, we demonstrate that when the nature of the citing patent is separated, the likelihood of a non-oil and gas patent mentioning oil and gas patent is greater, particularly when the patent is not exclusive and contains connections to environmental technology. These findings point to some directions for enhancing the efficacy of both environmental and technological initiatives.In a word, our primary finding is that, even in the best-case scenario, knowledge spillovers in the oil and gas sector are small. This suggests that technological policy tools aimed at addressing environmental advances in this area are underperforming. Environmental policy, on the other hand, should play a key role in promoting green technology. In this regard, our contribution contributes findings to address the scarcity of data on the efficacy of public R&D spending as part of the technological policy mix to combat climate change.

The actual costs of environmental harm are rarely reflected in the market pricing of fossil fuels with very few exceptions across the globe, resulting in inefficiencies, reducing the incentives to decrease these sources of energy, and therefore impeding the adoption of clean energy. A rebalancing of the policy mix would be needed to successfully encourage the use of environmentally friendly technologies in the oil and gas industry, decreasing the role of technological instruments and relying more heavily on environmental policy instruments. This would hasten the phase-out of substantial but wasteful oil and gas subsidies, especially those linked to fossil fuel research and development. Indeed, according to the OECD (2012), IEA countries across the globe have spent between US$ 1.4 and US$ 1.8 billion on fossil fuel R&D in recent years, with just around 10% of it going to clean technology like CCS. Our findings indicate that, although public funding may have aided in increasing innovation in the industry, only a tiny portion of it is devoted toward environmental protection[9].

This shift would need a greater reliance on MBI in environmental policy. More clear pricing signals, in particular, would be required to encourage sufficient emissions reductions in order to combat climate change and ensure environmental sustainability. To this aim, well-designed tools (additional levies or better carbon trading systems) would be a useful tool for dealing with the many dangers presented by the global climate crisis. These MBI may provide the right incentives for decision-makers to embrace conservation, encourage dirty-to-clean energy substitution, and stimulate innovation in the industry, in addition to reducing the amount of emissions. Complementary policies, such as eco-labels, voluntary agreements, or "green" public procurement, may also be used to rebalance the policy mix, ensuring that all potential synergies among the various instruments are taken advantage of. According to our findings, governments all around the globe should focus on improving technical skills in this area. Given the significant complementarities between technology and environmental policy, tangible measures should be made at the sectoral, national, and international levels to improve policy coherence. Environmental policies are developed and executed at the national level, with only a limited amount of international collaboration. Large consumers of carbon resources are opposing MBI adoption, which is a significant setback for global climate change mitigation efforts. According to the World Bank , the number of nations employing these types of instruments is currently relatively small[10].

If one of the major energy companies ultimately adopts MBI as a key component of its environmental strategy, a propagation effect may occur. As a result, global action is required – at least in the oil and gas industry – since nations cannot safeguard their own climate and environment on their own. This necessitates the modification and expansion of international environmental accords in order to promote greater innovation and, in particular, technological dissemination. They may increase innovation and technology transfer in leading nations or industries by raising demand for environmentally friendly technologies. However, the instruments employed will have a significant impact on their efficacy. Although recommend using technology-oriented rather than emission-oriented equipment, our findings for the oil and gas sector indicate otherwise.Our work may be expanded in a variety of ways. First, expanding the study to other sectors with significant environmental effects, such as the electricity industry, would be intriguing. Second, although we've focused on inter and intraindustry spillovers, knowledge diffusion may occur in a variety of ways, including across nations (especially developed and developing), applicant types (for example, businesses, governments, or institutions), and the temporal profile of citations. Finally, there is growing worry about the impact of environmental technologies crowding out other technologies, necessitating an examination of the technologies that are being replaced. All of these issues are important to help policymakers fine-tune future environmental and technological regulations. Even though energy liberalization has increased the quality of policy measures to minimize negative environmental effects, according to Pollitt (2012), the transition to a low-carbon economy is largely dependent on how much societies are prepared to accept the significant costs involved[7].

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