



The diffusion of patented oil and gas technology with environmental uses: A forward patent citation analysis



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HIGHLIGHTS

- Knowledge spillovers from oil and gas inventions are of an intrasectoral nature.
- Environmental uses in original patents diffuse to patents with environmental uses.
- The “turnabout” effect converts low quality patents into high quality citing patents.
- Diffusion of oil and gas inventions need more ad hoc instruments.

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ABSTRACT

Relevant advances in the mitigation of environmental impact could be obtained by the appropriate diffusion of existing environmental technologies. In this paper, we look at the diffusion of knowledge related to environmental technologies developed within the oil and gas industry. To assess knowledge spillovers from oil and gas inventions as a measure of technology diffusion, we rely on forward patent citations methodology. Results show that there is a strong likelihood that the citing patent will be eventually linked to environmental technologies if the original oil and gas invention has already environmental uses. Moreover, both intra and intersectoral spillovers produce a “turnabout” effect, meaning that citing patents show the opposite quality level of the cited patent. Our results support the idea that more sector-specific environmental policies, with an emphasis on diffusion, would significantly improve the use of environmental technologies developed within the oil and gas industry.

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1. Introduction

Since its origins, the petroleum¹ industry has undoubtedly contributed to the world's economic growth, to the generation of wealth, has enhanced prosperity and has certainly pushed the standards of living in many countries. In spite of substantial penetration of renewable energies in recent years (Aguirre and Ibi-kunle, 2014), the sector has remained central to the energy industry. Moreover, in spite of its perennial crisis (Mitchell and

Mitchell, 2014) it is expected it will maintain this role for some time into the future (IEA, 2013). For instance, the sector covers nearly all of the energy requirements for transportation in the world and supplies a vast amount of raw materials for chemical products and processes (Hughes and Rudolph, 2011). The oil shocks of the 1970s have been the sole disruptions to an otherwise always increasing production trend during the 20th and the 21st centuries. Moreover, higher demand from developing countries will keep the production trend up, according to the conservative scenario for 2035 elaborated by the International Energy Agency (IEA, 2013).

As with many other economic activities, the oil and gas industry generates externalities – unintended positive or negative consequences on other economic and social agents that are not captured by the price mechanism. In this respect, some oil and gas energy sources have important negative effects on the environment. For instance, greenhouse gas (GHG) emissions and other

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¹ The petroleum industry includes the exploration, extraction, refining, transportation and commercialisation of oil and gas products. In this paper we will refer to oil and gas industry or petroleum industry.

pollutants are produced by the combustion of fossil fuels. Oil spills and additional by-products of refining discharged in lakes, rivers and the sea account for a significant amount of water pollution (Höök and Tang, 2013). To correct these market failures, environmental policies are needed to balance out marginal costs and benefits of environmental protection. Technologies such as carbon capture and sequestration (CCS) and flue-gas desulfurisation (FGD) to name just two of the most widely known inhibit CO₂ and SO₂ emissions respectively (Yeh and Rubin, 2012). Technology can be used to reduce the cost per unit of energy or to improve the energy requirements to carry out activities and thus is welfare improving.

According to Carraro et al. (2010), by changing relative prices, environmental policies induce technical change towards so called clean technologies. These are technologies that are supposed to deliver the same amount of goods and/or services with less environmental degradation. The change in relative prices comes from the application of different policy tools that normally lie within two broad groups: market based instruments (MBI) and command and control instruments (CAC). The latter refer to measures that establish constraints on the volume of pollution each agent can generate. The former set up explicit prices for negative environmental externalities by means of taxes, tradable pollution permits or fees, among others.

The mitigation of these negative environmental effects produced by the petroleum industry and related activities can also be tackled from the perspective of technology policy. In this case, for instance R&D subsidies for clean technologies can be designed to promote complementary private investments to develop new inventions or modifications to existing ones that alleviate the negative environmental impacts of human activities. Both environmental and technology policies are justified by the existence of two different types of externalities, a situation normally referred to as the “double externality problem” (Carraro et al., 2010).

The case for environmental policy comes from the fact that without appropriate incentives, agents will not be able to benefit from their efforts to protect the environment and this generates an above-optimal level of pollution. The externality associated to R&D and innovations policies relies on the appropriability argument, stating that once the knowledge supporting a new technology or invention is disclosed, it is available to other agents to copy it and negatively affecting the benefits to the inventor causing a sub-optimal level of R&D investment. These arguments make clear that energy and the environment are naturally linked by technology. In this respect, energy policies, environmental policies and technology policies are strategically interconnected and each one has to be designed taking the others into account to enhance their effectiveness.

By promoting the generation of novel clean technologies, environmental policy is said to induce eco-innovations (del Rio et al., 2010). There is a large literature concerned with the role of environmental policy to promote the development of new technology by means of innovation (see Jaffe et al., 2002; Carraro et al., 2010 for surveys). However, an additional approach would be to consider that relevant advances in the mitigation of environmental impact could also be obtained by the appropriate diffusion of existing environmental technologies (Popp et al., 2011).

Diffusion of new technology is known to be a slow process. Jaffe et al. (2002) indicate two potential factors that explain this pattern. On one hand, the expected value of the new technology will vary with the heterogeneity of potential adopters. If adopters are very different, the penetration rate of the new technology will be normally low, at least during the first stages of its development. On the other hand, the adoption of new technology implies an uncertain amount of risk. Prior to adoption, information regarding the relevant characteristics of the novel technology would have to

have been diffused first. In addition, Carraro et al. (2010) argue that uncertainty also enters the slow rate of technology diffusion equation. When agents observe a rapid rate of innovation, they will expect a fast degree of technological obsolescence and hence they will be reluctant to adopt the technology. These authors also assert that there is sufficient evidence to support the notion that environmental policy is a relevant instrument to promote innovation and enhance diffusion of novel environmentally-friendly technologies. Here, we will look at the diffusion of knowledge related to environmental technologies developed within the oil and gas industry.

In this paper we focus on the diffusion of patented oil and gas technologies, with an especial focus on the environmental uses these inventions declare to have. Since the petroleum industry is responsible for an important amount of the adverse impact on the global environment, knowing to what extent technologies developed within this sector embrace environmentally friendly uses is of great importance to the design of future energy and environmental policies as well as to inform international climate change negotiations. To study knowledge diffusion from oil and gas patented inventions we rely on patent applications and citations to patents as a measure of knowledge diffusion (Jaffe et al., 1993).

The paper is organised as follows. In Section 2 we describe the data, we discuss the advantages and drawbacks of patents as measures of technology inventions and we clarify how citations can be used to track technological diffusion. We also expose the empirical methodology to be used in the analysis of forward patent citations in the oil and gas industry. The results are then presented in Section 3 along with the discussion of the main findings. Finally, Section 4 contains the conclusions of the research. Here, particular emphasis is put on the policy dimension.

2. Data and methods

In this section we first describe the dataset used to analyse the diffusion of patented oil and gas technologies and we discuss some advantages and some drawbacks of patents as indicators of invention. In addition, we conduct an explanatory and descriptive analysis of the data. Finally, we explain the methodologies we use for the empirical analysis of forward citations, namely a count data model to assess citation counts (Hausman et al., 1984) and a multilevel model (Wooldridge, 2003) in order to capture the characteristics of both the citing and the cited patents.

2.1. Patents data and exploratory analysis

The objective of this paper is to analyse the diffusion of patented oil and gas technologies. Although several indicators are available for that purpose we will focus on forward patent citations to examine the extent of knowledge spillovers arising from oil and gas inventions. Citation linkages from one patent to another patent are believed to be valuable – although imperfect – mappings of knowledge flows (Hall et al., 2005).

Patent data have a number of attractive features for the analysis of the interactions between technology and the environment (Popp, 2005). For example, the technological breakdown for which patents are available is quite detailed, making them a suitable indicator for the analysis of technology invention and diffusion. Moreover, patents contain citations to previous inventions, as patent applicants are required to include references to previous patents that have been used to develop the new technology or knowledge described in the patent. Hence, they represent a form of knowledge and/or technology flow (Jaffe et al., 1993). However, there are also some issues to take into account. Not all inventions are patented, so patent citations may underestimate the real

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