



Energy security and climate change: How oil endowment influences alternative vehicle innovation



Jung Eun Kim*

Department of Public Administration, Center for Environmental Policy Administration, The Maxwell School, Syracuse University, 419 Crouse-Hinds Hall, 900S. Crouse Avenue, Syracuse, NY 13244-1020, USA

HIGHLIGHTS

- I examine the effect of oil endowment on technology innovation in the transportation sector.
- An empirical model was developed for a cross-country analysis of oil endowments.
- A country's oil endowment is a negative driver of alternative technologies.
- Energy price is a positive driver of alternative technologies and energy efficiency technology.
- Implications for domestic and international climate policy are discussed.

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ABSTRACT

Fast growing global energy needs raise concerns on energy supply security and climate change. Although policies addressing the two issues sometimes benefit one at the expense of the other, technology innovation, especially in alternative energy, provides a win–win solution to tackle both issues. This paper examines the effect of oil endowment on the patterns of technology innovation in the transportation sector, attempting to identify drivers of technology innovation in alternative energy. The analysis employs panel data constructed from patent data on five different types of automobile-related technologies from 1990 to 2002: oil extraction, petroleum refining, fuel cells, electric and hybrid vehicles (EHV) and vehicle energy efficiency. I find that countries with larger oil endowments perform less innovation on refining and alternative technologies. Conversely, higher gasoline prices positively impact the patent counts of alternative technologies and energy efficiency technology. The findings highlight the challenges and importance of policy designs in international climate change agreements.

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1. Introduction

Concerns about combating climate change have led to serious debates on fossil fuel usage; however, those concerned with energy security, with the goal of an economically stable energy supply, often advocate the use of fossil fuels. In the search for a win–win solution to tackle both these pressing problems, technology innovation, especially in alternative energy, provides an opportunity to solve the two problems at the same time by reducing greenhouse gas (GHG) emissions and decreasing countries' dependence on imported fossil fuels. Among the many sectors using fossil fuels, the transportation sector heavily relies on fossil fuel use and is the second largest sector, emitting 23% of world carbon dioxide (CO₂) as of 2009 (IEA, 2011). It is a pressing

task to analyze the rate and the drivers of technology innovation for climate change mitigation and energy security within the transportation sector. Thus, this paper examines the effect of crude oil endowments, a driver of innovation related to both climate change and energy security, on the patterns of technology innovation in the transportation sector.

As a measure of technological innovation, I constructed a panel of patent data for five different types of automobile-related technologies: oil extraction, oil refining, fuel cells, EHV and vehicle energy efficiency. A brief look at the patent data indicates different patterns of technology innovation emerge across countries depending on their oil endowment. For example, Germany and Japan, each with low oil reserves, show high levels of patenting in alternative energy technologies compared to other technologies within those countries, while Norway and Canada, each with higher oil reserves, show high levels of patenting in oil extraction technologies. It is obvious the different patterns of patenting in various countries correlates to the presence of

* Tel.: +1 315 443 1890; fax: +315 443 1075.

E-mail address: jkim142@maxwell.syr.edu

industries. The existence of the oil extracting industry, for example, leads to oil extracting patents, while vehicle patents are driven by vehicle industry. However, patterns of vehicle patents vary among countries by oil endowment. Particularly, low oil reserves are associated with high patenting in alternative vehicle technologies. This paper focuses on this relationship between oil endowment and patents in alternative vehicle technologies.

This study contributes to the literature in two ways. First, it fills an important gap in the analysis of energy-related technological change. Although the transportation sector is a key part of most economies, and by far the biggest consumer of oil, almost all of the previous literature on energy and technology innovation focuses on the electricity sector. Second, it connects the energy security and climate change issues by studying technology innovation that provides a vision for a win–win solution for both energy security and climate change mitigation. In doing so, it expands the existing list of the drivers of technology innovation related to fossil fuel use by empirically testing the effect of oil endowment on the patterns of technology innovation. This study shows that decisions to innovate appear to take energy security into consideration, as well as climate change, in sectors using fossil fuel energy.

In the next section, I review previous studies regarding determinants of technology innovation. In Section 3, the theory of how country-level oil endowment affects patterns of technology innovation is discussed and in Section 4, the patent data in this study are described. Explanatory variables are described in detail in the fifth section followed by the empirical model and its result in Section 6. Section 7 will conclude the paper.

2. Literature review

Studies on the determinants of technology innovation in the energy sector have focused on two main drivers of technology innovation: energy price (Popp, 2002; Newell et al., 1999) and government policies (Fischer and Newell, 2008; Popp, 2006; Johnstone et al., 2010).¹ The heightened attention on seeking technological solutions regarding climate change led to more recent studies focusing on the power of government policies in inducing clean energy technology innovations (Lanjouw and Mody, 1996; Popp, 2006; Greene, 1990). Contrarily, studies on natural resource scarcity as a determinant to technology innovation are mostly theoretical or based on simulation models (e.g. Bretschger, 2005).

As a determinant of technology innovation frequently studied, government policy emerges in two forms: public R&D and policy measures, such as incentive systems. Public R&D may initiate private R&D. David et al. (2000) survey literature on the effect of public R&D on private R&D that led to innovations. A series of empirical studies finds a positive effect, which implies that public R&D can serve as a complement to private R&D. Similarly, Hascic et al. (2008) find that governmental public R&D increases environmental technology innovation in environmental pollution abatement.

Government policy measures are another governmental intervention inducing technology innovation (Fischer and Newell, 2008; Popp, 2006; Johnstone et al., 2010). Fischer and Newell (2008) examine renewable energy policies in the electricity sector. They find that a portfolio of policy measures is more effective in reducing GHG emissions than a single policy measure. Johnstone et al. (2010) look at the effects of both price-based and quantity-based policies on renewable energy innovation from 25 OECD

countries.² In general, they find that policies have a significant impact on renewable energy innovation. However, price-based and quantity-based policies exhibit different levels of effects on different technologies. Non-financial policies that allow firms to choose technologies stimulate cheaper technologies, whereas financial policies that guarantee a market price promote more expensive technologies (e.g. feed-in-tariffs on solar energy).

Regarding indirect measures of energy resource scarcity, several studies empirically test the effects of energy prices on induced innovation. Popp (2002) tests the effects of energy prices on energy efficiency innovation and finds a strong effect of energy price on energy efficient innovation, as measured by patent counts. Newell et al. (1999) test both the effects of price and regulation on technology innovation in home appliances. They find that neither price changes nor environmental regulation have a dominant effect on technology innovation. On the other hand, Greene (1990) finds that the Corporate Average Fuel Economy standard has a stronger effect on fuel economy than changes in fuel price.

Regardless of their focus on either price or government policy (or both), these studies frequently look at the electricity sector (Popp, 2002; Fischer and Newell, 2008; Johnstone et al., 2010; Lanjouw and Mody, 1996; Newell et al., 1999). However, Greene (1990) and Van Den Hoed (2007) are the exceptions; they study the automobile industry. Greene (1990) measures innovation through the improvement in fuel economy, which shows the possible results of accumulated knowledge but not the amount of accumulated knowledge. Van Den Hoed (2007) analyzes what factors cause technological change from combustion engine to fuel cell technology in private investment in the automobile sector. He finds that government regulation coupled with significant technical progress contributes to high investment in the fuel cell technology. Although his analysis provides insights on the fuel cell technology for automobiles, his analysis is mostly descriptive. To fill the gap in the literature, this study empirically examines the effect of oil endowment as another determinant of technology innovation.

3. Theory

Previous studies identify policies (Fischer and Newell, 2008; Popp, 2006; Johnstone et al., 2010) and energy prices (Popp, 2002; Newell et al., 1999) as determinants of energy technology innovation. The literature on technology innovation does not explicitly consider the oil endowment of a country as a direct determinant. However, from the socio-political perspective, resource endowment directly relates to energy security of a country. Reflecting the interconnectedness with energy security, this paper posits that studying technology innovation may include oil endowment as one of its direct determinants and aims to identify the impact of oil endowment on the pattern of innovation in the automobile sector across countries.

In the automobile sector, the connection between oil endowment and automobile technology innovation is not obvious because of the highly integrated world markets for automobiles and oil. Oil and automobile are complementary goods because oil is the dominant energy input for automobiles—oil price and supply highly affect vehicle sales. Customers facing high fuel prices prefer more efficient or alternative vehicles rather than the conventional ones, thereby increasing the demand for efficient or alternative vehicles. Driven by the increased consumer demand, automobile firms decide to invest in innovation for alternative vehicles not

¹ See Jaffe et al. (2003) and Popp et al. (2010) for more complete lists of literatures.

² OECD is the Organization of Economic Co-operation and Development.

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