Energy Policy 97 (2016) 27–38

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Innovation in the energy sector – The role of fossil fuels and developing economies

Elina Brutschin [a,*], Andreas Fleig [b]

[a] International Relations Department, Webster University Vienna, Praterstrasse 23, A-1020, Vienna, Austria
[b] Department of Political Science, Heidelberg University, Bergheimer Str. 58, D-69115 Heidelberg, Germany

HIGHLIGHTS

- We investigate a sample of 116 countries, a pool beyond the commonly considered OECD members.
- We find that high oil prices induce increased R&D expenditures in developed countries.
- Fossil rents are associated with decreasing patent grants when developing economies are included.
- We use multiple imputation to handle the problem of missing data.

ARTICLE INFO

Article history:
Received 17 November 2015
Received in revised form
16 June 2016
Accepted 25 June 2016

Keywords:
Energy sector
Innovation
Fossil fuels
Patents
R&D expenditures

ABSTRACT

This paper analyzes the effects of fossil fuel rents on R&D expenditures and patent grants in the field of energy-related technology. We argue that an increasing share of fossil fuel rents lessens the innovation of new energy technologies. We consider a sample of countries beyond the common selection of OECD members and investigate innovation efforts in the energy sector of 116 countries from 1980 to 2012. We observe the gradually growing influence of resource-abundant countries on global R&D expenditures and find that increasing fossil fuel rents have a negative effect on patent grants. This study contributes to the ongoing debate concerning the potential effects of resource abundance. More importantly, it increases our understanding of innovation activities within the energy sector and further underscores the need to extend future research to countries that have not been taken into account thus far.

1. Introduction

As "affordable energy is the lifeblood of modern society" (Holt, 1999, p. 662) it is not surprising that issues, such as ever-rising energy consumption (IEA, 2015a) and increasing resource scarcity (Brown et al., 2014), have been linked to civil and international conflicts (Colgan, 2011; Homer-Dixon, 1994) or the global challenge of climate change (IPCC, 2014; IEA, 2015b). This turns energy security into one of the key factors in achieving a stable and sustainable international regime (Mueller-Kraenner, 2008; Yergin, 2006). In this respect, technological innovation plays an important role, as it might increase global energy security and thereby attenuate geopolitical concerns. Despite the prevailing "consensus on the economic and environmental benefits of developing new energy technologies" (Costa-Campi et al., 2015, p. 193), only a small proportion of energy studies discusses its influence and potential effects, meaning that "our knowledge on how to foster [innovation] remains insufficient" (Costa-Campi et al., 2015, p. 193).

Innovation has been investigated across many different disciplines (for an overview see Crossan and Apaydin (2010), Garcia and Calantone (2002) and Prajogo and Sohal (2001)), bringing along a variety of potential definitions of the term, each of which has been strongly influenced by the respective epistemic community (Carlsson et al., 2002). As every conceptualization has specific ramifications for research and its broader policy-relevant context, we deliberately choose our approach to differ from the concept of (sectoral) systems of innovation (Malerba, 2002). Instead, we concentrate on the operational definition of innovation by looking at both the input (R&D expenditures) and the output side (patent grants) of the innovation process (Sagar and Holdren, 2002).

Informed by the concept of induced innovation (Popp, 2002, 2016), we focus our analysis on the effects of fossil fuel rents[1] on

* Corresponding author.
E-mail addresses: elina.brutschin@webster.ac.at (E. Brutschin), andreas.fleig@ipw.uni-heidelberg.de (A. Fleig).

http://dx.doi.org/10.1016/j.enpol.2016.06.041
0301-4215/

[1] Analogous to the definition used by the World Bank of natural resources rents, we define fossil fuel rents throughout our analysis as the difference between resource production at world prices and their total cost in percentage of GDP.

innovation processes. Fossil fuels dominate the world energy market as the main source of energy production and consumption (IEA, 2015a; OECD, 2012). Still, their increasing rate of consumption (Azevedo, 2014) feeds off deposits that are unevenly distributed and finite. In this context, one key instrument in strengthening long-term energy security becomes finding viable substitutes or improving extraction rates through innovation. In contrast, energy producers might suffer under the so-called "resource curse" (Frankel, 2010; van der Ploeg, 2011; Sachs et al., 1995), which could slow down their innovation efforts. In the following, we test whether a systematic relationship exists between rents in fossil fuels and the innovation process in the energy sector.

One major contribution of our study is that we include countries beyond the Organization for Economic Co-operation and Development (OECD) members and therefore consider the role of both energy consumer as well as producer countries. This supplements previous work, which mainly investigated samples of International Energy Agency (IEA) or OECD countries (Alic et al., 2010; Anadon, 2012; Baccini and Urpelainen, 2012; Bointner, 2014; Cheon and Urpelainen, 2015; Lanjouw and Mody, 1996; Popp, 2002; Sagar and Holdren, 2002; Wangler, 2013). This focus is understandable, as available country-level data on innovation and research funding is almost exclusively limited to these economies. To extend the widely studied sample of highly developed countries, we join current efforts (Huang et al., 2012; Kempener et al., 2014; Lewis and Wiser, 2007) and broaden our investigation based on the three following motivations.

Firstly, it is true that for a long time industrialized countries have dominated innovation in the energy sector. This common argument that "most developing countries have little capacity for energy technology innovation" (Cheon and Urpelainen, 2012, p. 410) was strengthened by empirical analyses such as Bointner (2014, p. 738) who found that the US, Japan and Germany possess the largest knowledge in the field of renewable energy technologies. However, more recent data compilations (Kempener et al., 2014) point out the role of the economies of Brazil, Russia, India, Mexico, China, and South Africa (BRIMCS) in innovation activities. One notable example is China, which is currently evolving into one of the biggest promoters of R&D in the energy sector (see Section 3.1 and Lu (2013)) and a key patenting country in geothermal energy, carbon capture, and storage (Bointner, 2014, p. 741). It is, therefore, increasingly important to understand the influence of these countries on the world energy market and to identify possible differences and peculiarities of their innovation process (Dannreuther and Ostrowski, 2013).

Secondly, while previous studies state that concentrating on OECD countries does not bias findings (Cheon and Urpelainen, 2012), we argue that a study on a larger sample of countries is necessary. Observing absence of patent activity contains important information for the test of existing hypotheses. Indeed, it is essential to include developing countries and explore the variation in their innovation inputs and outputs.

Thirdly, the share of OECD countries in worldwide total primary energy supply has shrunk from 61.3% in 1972 to 39.2% in 2012 (IEA, 2014, p. 8). Aside from the shale-gas revolution (Stevens, 2012), only non-OECD members offer growth markets for commodity exploitation (IEA, 2014, 2015a, p. 47). Moreover, BRIMCS have enormously increased the scope of their R&D activities in the energy sector since the early 2000s (see Section 3.1). Of course, as many of these countries are currently experiencing low economic growth, this might also affect their future R&D spending. Yet, their positions, such as major commodity exporter (Russia) or energy consumer (China, India), set them out to become principal actors in shaping the future development of innovation efforts in the energy sector.

The remainder of this paper is structured as follows. Section 2.1 starts by reviewing previous literature and elaborates our hypotheses. In Section 2.2 we discuss data sources and methodological issues. Section 3 presents the findings in two steps. The first gives an overview of the descriptive findings, while the second presents the findings of our time-series cross-section estimations. Section 4 concludes and evaluates policy implications of our research.

2. Methods

2.1. Literature review and main hypotheses

The literature on innovation in the energy sector can be broadly divided into two categories. While studies following the idea of an innovation system focus mainly on grand patterns of technological change (Grubler and Nemet, 2014; Jacobsson and Bergek, 2004), a second strand of contributions investigates political and economic factors that might influence innovation activities (Cheon and Urpelainen, 2012; Geller et al., 2006). In addition, the literature can be further subdivided based on whether the level of analysis is set at the firm (Costa-Campi et al., 2015), state (Bointner, 2014), sector (Iyer, 2016), or technological level (Jacobsson and Johnson, 2000).

The political economy perspective on innovation in the energy sector looks into the effects of the prevailing market and polity institutions. Here, positive and negative market shocks as well as certain policies can induce innovation (Popp, 2016, 2002). Our particular interest lies with the strand of political economy literature that looks into innovation input and output activities at the state level. Here, governments can create positive path-dependencies that will induce market incentives for the development of new sectors and technologies (Lund, 2009). In this context scholars have investigated the role of R&D spending in the energy sector on the level of innovation output (Costa-Campi et al., 2015). Empirical studies also show that the amount of R&D expenditures correlates strongly with patent activities when allowing for a time lag (Prodan, 2005). We therefore include R&D expenditures as one of the major explanatory factors for the level of patent activity in our models. Still, the proposition that higher R&D spending leads to more innovation output is contested. For example, Archibugi et al. (2009) and Mahroum and Al-Saleh (2013) showed that similar expenditures (inputs) can lead to very different innovation levels (outputs) across several countries. While we agree that the link between R&D expenditures and patent activity is conditioned on many additional factors, we contribute to the ongoing debate by testing the following hypothesis:

Hypothesis 1. Countries with higher R&D expenditures register a larger number of patent grants in the energy sector.

From a market perspective, energy prices are one of the key variables that affect innovation incentives of a broad spectrum of actors (Acemoglu, 2003; Popp, 2016). High prices indicate excess demand and thereby create incentives for additional production or substitution by alternative resources. Low energy prices reduce these incentives vice versa (for a more detailed description of oil and gas market structures see Krichene (2002)). The theoretical argument on energy prices is also backed by empirical evidence. For instance, increasing oil prices have been found to reinforce innovation within developed renewable energy sectors (Cheon and Urpelainen, 2012) and the transportation sector (Kim, 2014). This leads us to the following hypotheses, where we consider R&D expenditures and patents as two separate dependent variables:

Hypothesis 2a. Higher energy prices induce an increase of R&D