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Technology and demand forecasting for carbon capture and storage technology in South Korea

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HIGHLIGHTS

- Carbon capture and storage (CCS) can help mitigate climate change globally.
- It can both improve economic growth and meet GHG emission reduction targets.
- We forecast CCS technology and demand based on an integrated model.
- The US has the most competitive CCS technology followed by Korea and France.
- 5 million tCO_2e of GHG will be reduced by 2040 if CCS is adopted in Korea.

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ABSTRACT

Among the various alternatives available to reduce greenhouse gas (GHG) emissions, carbon capture and storage (CCS) is considered to be a prospective technology that could both improve economic growth and meet GHG emission reduction targets. Despite the importance of CCS, however, studies of technology and demand forecasting for CCS are scarce. This study bridges this gap in the body of knowledge on this topic by forecasting CCS technology and demand based on an integrated model. For technology forecasting, a logistic model and patent network analysis are used to compare the competitiveness of CCS technology for selected countries. For demand forecasting, a competition diffusion model is adopted to consider competition among renewable energies and forecast demand. The results show that the number of patent applications for CCS technology will increase to 16,156 worldwide and to 4,790 in Korea by 2025. We also find that the United States has the most competitive CCS technology followed by Korea and France. Moreover, about 5 million tCO_2e of GHG will be reduced by 2040 if CCS technology is adopted in Korea after 2020.

1. Introduction

Abnormal climate changes globally from the late 20th century have caused natural disasters such as typhoons, heavy rain, and storms, increasing both economic and non-economic losses. Indeed, the additional cost necessary to respond to climate change is estimated to be around 1% of aggregate GDP (Stern, 2007). In addition, failing to address climate change in a timely manner will lead to damage ranging from 5% to 20% of GDP. According to Intergovernmental Panel on Climate Change (2014), if the trend of climate change is assumed to be similar worldwide, the global mean surface temperature in 2100 will increase by around 3.7–4.8 °C compared with the average temperature from 1850 to 1900. What is worse, the temperature change will range from 2.5 to 7.8 °C if climate uncertainty is considered. In particular, a temperature rise of more than three degrees Celsius will harm biological diversity and the ecosystem (Intergovernmental Panel on Climate Change, 2014).

Given the rising awareness of this problem and the upcoming risks, each government has planned various policies. For example, South Korea's (hereafter Korea) government has targeted a reduction in greenhouse gas (GHG) emissions of 37% from business-as-usual levels by 2030, and it submitted this goal to the United Nations Framework Convention on Climate Change in June 2015. To achieve this goal, Korea's government has implemented

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successive policies and institutions to develop GHG reduction technology.

Renewable energy, nuclear power, and energy-efficient technologies can all serve to reduce GHG emissions (International Energy Agency, 2015). However, public acceptance of nuclear power generation has decreased since the Fukushima disaster. The implementation of energy efficiency technologies has grown because of their contribution to the economy as well as ability to reduce GHG emissions. Power companies under pressure to reduce GHG emissions typically select the appropriate renewable energy technology or a combination of carbon capture and storage (CCS) system and thermal power plant after conducting feasibility tests. While CCS technology is likely to compete with renewable energies and alternative technologies (Akbilgic et al., 2015; Mansouri et al., 2013), an appropriate policy orientation and strategic perspective are still insufficient. In light of this research gap, it is necessary to build an integrated model to forecast CCS technology and demand that incorporates market changes and the technological competitiveness of related technologies. To fulfill this objective, this study presents an integrated model that combines patent network analysis for technology forecasting and a competition diffusion model for demand forecasting. Renewable energy sources, as alternative approaches to reduce GHG emissions, are included in the diffusion model to consider the competitive market situation.

This study has two distinctions from the existing literature. First, the model is proposed by integrating technology competitiveness analysis with the number of patent applications for each country and diffusion considering competition with renewable energy sources. Second, while many studies mainly examine the effects of CCS adoption by using qualitative methods (Arranz, 2015; Kern et al., 2016; Marshall, 2016; Setiawan and Cuppen, 2013; Xu and Liu, 2015), this study conducts a quantitative analysis given the body of empirical evidence. The research framework of this study is depicted in Fig. 1.

The remainder of this paper is organized as follows. Section 2 reviews the CCS technology trend and policy in Korea and examines the related literature. Section 3 explains the estimation model based on patent analysis and a competition diffusion model. Section 4 describes the patent and cost data used in the analysis, and Section 5 presents the estimation results. Finally, Section 6 suggests implications and concludes.

2. Background

2.1. CCS technology trend and policymaking in Korea

CCS is a technology that captures and stores the CO_2 generated from thermal power plants or steel plants, and transports it to specific spaces for sequestration. It is particularly useful for reducing GHG emissions while fossil fuels are continuously used. The international importance of CCS has been demonstrated at G8 summit meetings (International Energy Agency, 2009). For example, CCS commercialization by 2020 was agreed in June 2008 and large-scale demonstration projects and supporting programs for each country were shared in June 2010. Among GHG reduction technologies, CCS is increasingly considered to be significant, and it is predicted to account for a 13% reduction in total GHG emissions by 2050 (International Energy Agency, 2015). Because of GHG regulations, the amount of CO_2 captured and stored by CCS technology is forecast to rise from 16.4 million tons in 2014 to 64.8 million tons in 2019, an average annual increase of 31.6% (Technavio Research, 2015). The International Energy Agency, Carbon Sequestration Leadership Forum, and Global Carbon Capture & Storage Institute have initiated CCS technology development, and the United Nations Industrial Development Organization has published a CCS technology roadmap for industrial applications (United Nations Industrial Development Organization, 2011). Further, Shell's Quest project in Canada, which is one of the largest CCS demonstration projects (Kern et al., 2016), and the European CCS Project Network in the Netherlands, Norway, Spain, and the United Kingdom (Kapetaki et al., 2016) remain in progress.

The Ministry of Science, ICT and Future Planning in Korea has implemented the “Korea CCS 2020” program to focus on R&D in basic and core technology, while the Ministry of Trade, Industry and Energy has implemented the “Pilot Project for CCS commercialization” as well as the “R&D on Greenhouse Gas Reduction Technology” program to enter the global CCS market in the early phase. Similarly, the Ministry of Oceans and Fisheries has planned “Large-scale CO_2 Storage Technology Development in Deep Oceans” to build a national storage and develop transport and injection technology and the Ministry of Environment (MOE) has promoted “Non-CO_2 Reduction Technology Development” to obtain global warming reduction technology. Furthermore, several ministries, mainly led by the MOE, have published the “National Greenhouse Gas Emissions Reduction Roadmap 2020,” showing the government's commitment of the development and promotion of CCS technology (Ministry of Environment, 2014). However, the R&D roadmap of CCS technology after 2020 is not yet established and consequently forecasting the diffusion pattern of CCS technology and demand needs to be addressed.

2.2. Literature review on CCS technology

Since CCS technology can address both economic growth and climate change, various studies of CCS have been conducted. The literature can be categorized into three topics: analysis of the development of CCS technology, cost estimation of power generation after CCS adoption, and effect of GHG reductions.

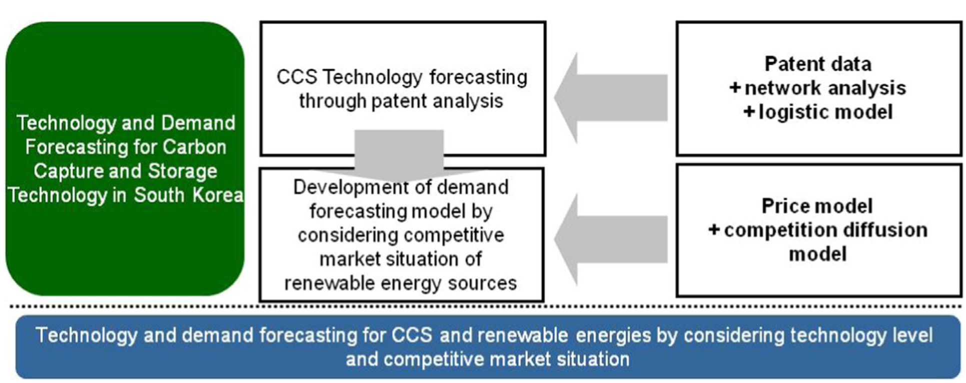

Fig. 1. A research framework of this study.