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The role of hydrogen energy development in the Korean economy: An input–output analysis

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ABSTRACT

Korea has been developing hydrogen energy technology to enhance its energy security. The Hydrogen Energy R&D Center established by the Korean government invested about 100 billion Korean won (KRW) into the development of hydrogen energy technology from 2003 to 2012. This study uses input–output (I–O) analysis, along with the scenario–based exogenous specification method, to investigate the effect of hydrogen energy technology investment on the Korean economy for the period 2020–2040. We focus on two perspectives: (1) the sectoral linkage effect and (2) the sectoral impacts of hydrogen energy supply investments. The overall results reveal that the hydrogen sector can be characterized as intermediate primary production because of its high backward and forward linkage effects. By 2040, total production in the hydrogen sector under two scenarios will be 13,484 and 2979 billion KRW, respectively. This study is a pioneering study into the assessment of the economy–wide effects of Korea's hydrogen energy industries.

Introduction

Hydrogen energy is a secure source of domestically produced and affordable clean energy [1]. Even though a number of obstacles to securing hydrogen energy exist [2], it is one of the most preferred alternatives to petroleum–based energy [3–6]. Several researchers and governments have attempted to assess the feasibility of hydrogen as an alternative energy source for their economies [2,7]. The US, the EU, and Japan have been increasing their R&D budgets to develop hydrogen energy and reduce their dependence on carbon energy [8]. Reflecting this trend, the Korean government has also been expanding R&D investment to develop hydrogen energy technology. Korea needs to diversify its energy portfolio by securing alternative energy sources [8].

Korea is the 10th largest energy–consuming country in the world and imports around 98% of its energy resources. This means Korea is sensitive to changes in crude oil prices. In addition, Korea was an affiliate to the Annex I party, which agreed to cap emissions by 2013 following ratification of the Kyoto Protocol [9]. However, Korea has relatively low energy efficiency because of rapid economic development from a heavy industrial base. For instance, the energy intensity of Korea was about 0.24 toe/1000 US$ in 2011 (base: US$ in year 2005). This is higher than developed nations such as Japan, the US, Germany, Italy, and the UK [10]. Previous studies on sustainable energy systems suggested that energy efficiency,

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Table 1 – Hydrogen energy sectors by commodity classification in I–O tables.

Large (28)	Medium (78)	Small (168)	Basic (403)
Chemicals, drugs and medicines	Basic chemical products	Inorganic basic chemical products	Industrial gases
General machinery and equipment	Machinery and general purpose equipment	Conveyors and conveying equipment	Conveyors and conveying equipment
Transportation equipment	Motor vehicles and parts	Motor vehicle engines and parts	Motor vehicle chassis, bodies and parts
Electricity, gas, steam and water supply	Electric utilities	Electric utilities	Other generation
Transportation	Land transport	Road transport	Road passenger transport

(): the number of sectors.

security, and environmental protection problems could be solved by academic and government agencies [2,11,12]. Since 1973, hydrogen energy technology has been developed by the Korean government because of its potential as an energy source. The government has chosen to develop hydrogen energy technology as a new engine of growth. The Ministry of Science and Technology (MOST) established the Hydrogen Energy R&D Center in the Korea Institute of Energy Research (KIER) in 2003 [8]. The KIER is a unique government–sponsored research institute specializing in the advancement of energy technology and policy [9]. The Hydrogen Energy R&D Center invested in the development of hydrogen energy technology from 2003 to 2012.

The most common energy economic models are linear programming (LP) models [6,13], computable general equilibrium (CGE) models [14,15], and input–output (I–O) models [1,16–21]. Among these models, I–O models are suitable for analyzing the economic ripple effect of new and renewable energy sources on other sectors [22]. Input–output model was introduced as a systemic quantifying method to investigate mutual interrelationships among numerous sectors within a complicated economic system [23]. The production process of each sector is expressed as the structure that is described in a quantitative manner by considering the absorption of inputs and production of outputs [24]. These models reflect current economic conditions using I–O table data. Many hydrogen–energy–related studies have also used I–O models [1,19,22]. One study analyzed the economic effects of biohydrogen development in the United States and China to 2040 [1]. They used a recursive I–O model taking into consideration technology advances and future economic structure.

This study applies an exogenous specification I–O model to investigate the production value of developing hydrogen energy technology from 2020 to 2040 in Korea. This study is pioneering research in analyzing the ripple effect of R&D investment on the development of hydrogen energy technology on other sectors for a period of 10 years in Korea. The results provide insight into the use of policy instruments related to hydrogen energy for policy makers and researchers.

Model and scenario design

Input–output analysis with exogenous specification

I–O analysis is an appropriate methodology for examining the impact of changes in expenditures, such as general expenses, investments, in each sector using I–O tables [25]. The I–O tables consist of total gross inputs and total gross outputs. Total gross inputs are divided into intermediate inputs from the supply sector and value added such as labor or capital inputs. Total gross outputs include intermediate outputs and final demands such as capital or consumption goods [26]. If the final demand for goods or services in a sector changes, the effect of the change on all industries can be obtained by direct or indirect interdependent relations among industries [17].

It is difficult to investigate the production-inducing effect of a specific sector on all other sectors of the economy using a standard demand–driven model. In order to overcome the difficulty, we use an exogenous specification which is a method to examine the impact of cost change in a specific sector on production cost of other sectors. In this paper, the hydrogen sectors are considered as exogenous and included in the final demand group. By using the method, we can theoretically find how the change in the cost of hydrogen sector influences other sectors in demand–driven model [27]. An exogenous specification method has increasingly been used in energy research, for example, four electric power sectors in exogenous sector highly influence input and output of other individual sectors in endogenous sector [17]. However, there are few empirical studies into hydrogen as a future resource using an exogenous specification, because the level of hydrogen technology is at an early stage and the market of hydrogen energy is small. In this paper, we investigate the effects of the hydrogen sector on Korean economy supported by the Hydrogen Energy R&D center, which has invested 100 billion Korean won (KRW) during 10 years. This R&D center aided the development of hydrogen energy technologies through a 10-year collaboration between universities and industry in Korea, and has been focusing on the development of technologies related to production, storage, and utilization for Korea's future hydrogen economy.

I–O tables for hydrogen energy in Korea

We used noncompetitive imports and domestic I–O tables for 2005 and 2009 distributed by Korea's central bank, the Bank of Korea (BOK) to examine the inter-sector effects [28]. We interviewed research directors in the Hydrogen Energy R&D Center to help identify the sectors related to hydrogen energy, because the I–O tables do not include the hydrogen sector because of its small size. They mentioned that the developed hydrogen energy technologies will directly and indirectly influence other industries by decreasing input costs and