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Korea's social dynamics towards power supply and air pollution caused by electric vehicle diffusion

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ABSTRACT

Korea has the highest air pollution among the Organization for Economic Co-operation and Development (OECD) countries. Since the recent environmental analysis (Kim et al., 2017) reported the feasibility of replacing taxis with electric vehicles (EVs) in metropolitan cities from a 'tank-to-wheel' emission perspective, various stakeholders have attempted to reduce air pollution by activating the EV market in Korea in accordance with international trends. Nevertheless, no holistic study has yet been published on the nationwide changes in air quality caused by EV diffusion from the perspective of 'well-to-wheel' emissions. This paper presents the results of estimating the stability of the electric power supply and fine particulate matter emissions in some cases, and the results of examining the structure of public discourse using big social media data. From the findings of our study, we made the following conclusions: (1) If the market share of EVs exceeds 12.5% before 2030 in Korea's domestic market, the supply and demand of stable energy will be threatened. (2) Under traditional energy mix conditions, the popularization of EVs may slightly reduce air pollution over metropolitan roads, but drastically increase air pollution near power plants that utilize fossil fuels. (3) Social media discussions show that the public is neither concerned about EVs being possible sources of pollutants, nor about potential instabilities in the energy market. (4) To obtain a socially acceptable energy mix, energy policy decision makers can select emission-free energy sources, such as nuclear power and renewable energy, depending on their priorities and based on power demand management to suppress excessive electrification.

1. Introduction

Road transportation is considered as an essential condition of economic development. However, it is also one of the main sources of air pollution in many countries (Karagulian et al., 2015). The percentage of air pollutants from vehicle emissions is increasing with the rapid increase in the number of vehicles, particularly in cities of developing countries. Reducing tailpipe emissions is emerging as an effective method of decreasing air pollution. In this regard, the diffusion of electric vehicles (EVs), which are believed to have no 'tank-to-wheel' emissions, is considered to be an important strategy for transportation (Nanaki and Koroneos, 2013). Through governmental initiatives, plans, and strategies, EVs are gradually replacing internal combustion engine vehicles (ICEVs) in many

Abbreviations: 2DS, IEA 2 °C scenario; BMW, Bayerische Motoren Werke AG; CAGR, Compound Annual Growth Rate; CAPSS, Clean Air Policy Support System; CORINAIR, CORe Inventory AIR emissions; EEA, European Environmental Agency; EG, electric generation; EPA, Environmental Protection Agency; EV, electric vehicle; FAA, Federal Aviation Administration; ICEV, internal combustion engine vehicle; IEA, International Energy Agency; KDI, Korea Development Institute; KEI, Korea Environmental Institute; KIET, Korea Institute for Industrial Economics & Trade; KIPF, Korea Institute of Public Finance; KTSA, Korea Transportation Safety Authority; LNG, liquefied natural gas; LPG, liquefied petroleum gas; MOTIE, Ministry of Trade, Industry, and Energy; MS, mobile source; NIER, National Institute of Environmental Research; NLP, natural language processing; OECD, Organization for Economic Co-operation and Development; $PM_{2.5}$, fine particulate matter; SNAP 97, Selected Nomenclature for sources of Air Pollution - year 1997; U.S., United States; VOC, volatile organic compound; WHO, World Health Organization.

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regions worldwide (IEA, 2016).

The annual number of days exceeding the atmospheric concentration standards for fine particulate matter ($PM_{2.5}$) in Korea is the largest among OECD countries. As $PM_{2.5}$ leads to 3.3 million annual premature deaths worldwide (Lelieveld et al., 2015) and contributes to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer (OECD, 2016), EV deployment is publicly considered as a method of mitigating $PM_{2.5}$ levels. Since Kim et al. (2017) reported the feasibility of replacing taxis with EVs in metropolitan cities, various local governments in Korea, including the Seoul Metropolitan Government, have attempted to reduce air pollution by activating the EV market in Korea in accordance with international trends.

Even though EVs appear "clean" as they may not cause emissions when driving, this characteristic is only true for 'tank-to-wheel' emissions. Given the 'well-to-wheel' emissions, there is still debate as to whether EVs release more pollutants than ICEVs. Prior studies reported that some of the environmental impacts from EVs were transferred from the usage phase to the production vehicle and electricity phases (Hawkins et al., 2013; Lave et al., 1995). Recent studies argue that the greenhouse gas emissions produced during the life cycle of EVs, from production to use, may not be lower than those of ICEVs (Ellingsen et al., 2016; Hofmann et al., 2016; Holland et al., 2016; Luk et al., 2016; Yuksel et al., 2016). In particular, Shi et al. (2016) studied the environmental impact of replacing gasoline taxis with EVs in Beijing, China, and reported that air pollution associated with $PM_{2.5}$ during the whole life cycle of electric taxis was higher than that of ICEVs.

In this article, we argue that the following points were not considered in the previous study (Kim et al., 2017) and therefore need to be addressed. First, the effect of pollutant emissions by EVs has been underestimated, because the previous study only considered 'tank-to-wheel' emissions, and not 'well-to-wheel' emission. That is, they compared the emission factors of electric taxis with those of liquefied petroleum gas (LPG) taxis, while the pollutants generated from electric power production, which is necessary for operating EVs, was not considered. To overcome the limitations of previous studies, the conditions for energy supply and mix should also be considered when adopting EVs. The second, which was not considered in the previous study, is that people did not faithfully consider the value of energy choice when adopting EVs. The choice of energy mix is a core theme of energy policy and is closely related to the value of people who are usually represented as the taxpayers' willingness to pay (Egbue and Long, 2012; Han et al., 2017; He and Zhan, 2018; Qian and Yin, 2017; Steinhilber et al., 2013; Stirling, 2008; Wang et al., 2017; Whitfield et al., 2009). As Yuan et al. (2017) demonstrated, the social acceptance of a particular technology, such as a nuclear power plant, can potentially affect energy and development planning. Therefore, when evaluating the effect of replacing ICEVs with EVs, we should consider that EV popularization will be consistent with the expectations of the public, including energy policy. To our knowledge, there are no previously published studies on social dynamics, including public awareness, as well as the effect of EV popularization.

To address these gaps and clarify the environmental impacts of EVs in Korea, we estimated the impacts of power supply stability and $PM_{2.5}$ emissions from EVs using a system dynamics model. To incorporate social acceptance, people's values were investigated by examining the structure of public discourse using big media data analysis. This paper is structured as follows. In Section 2, the methodologies are explained. Section 3 describes the estimation factors for endogenizing the exogenous EV diffusion variables in our original system dynamics model. The stability of the electric power supply, $PM_{2.5}$ emissions from EVs, and the structure of public discourse are examined in Section 4. The combined results and the policy implications are discussed in Section 5, leading to the conclusions in Section 6.

2. Methodology

To fill the two knowledge gaps presented in the introduction, we

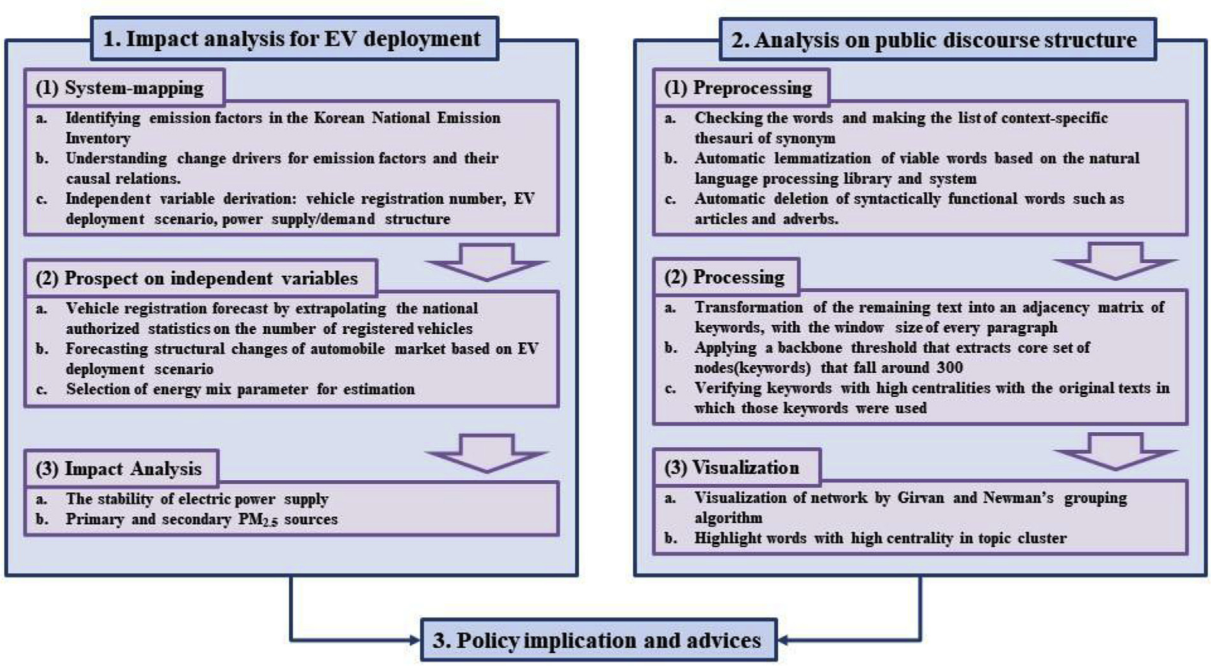

Fig. 1. Analytical framework.