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Product-Service Systems across Life Cycle

The Impact of the Popularization of Clean Energy Vehicles on Employment

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Abstract

The introduction of clean energy vehicles (CEVs) is expected to improve environmental efficiency in the transportation sector. However, the popularization of each CEV type has different impacts on economic, social, and environmental aspects across life cycle, because CEVs have a different parts structure from that of gasoline vehicles (GVs). Because CEVs affect many aspects of the social system, it is necessary to analyze CEVs in the context of product-service systems (PSS), which bring together products (CEVs) and service (public service), rather than focusing on individual products.

Also, the popularization of CEVs will affect employment especially, as CEVs generate demand in different industries compared with GVs. There are labor- and capital-intensive industries, and the number of jobs will vary depending on the supply chain characteristics of each CEV. However, most existing studies do not consider the impacts on employment when CEVs are popularized in a society. Therefore, by quantitatively assessing the social sustainability of PSS that are centered on CEVs and public service, in this study, we evaluate and analyze the ripple effects on employment under some scenarios. Our simulation results show that compared with 2010, the employment effects of the popularization of CEVs in 2030 are expected to decrease by about 37,000 people in Japan.

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Keywords: Automotive industry; Economic assessment; Employment effects; Input-output analysis; Life cycle; Product-service systems; Supply chain; Sustainability

1. Introduction

Ever since the publication of “Our Common Future” [1] by the World Commission on Environment and Development, there has been a gradually increasing interest in sustainability. Global warming is the leading sustainability issue and steps need to be taken particularly in the sector of “Transport”, which is responsible for approximately 23% of the total CO_2 emissions [2].

One of the measures undertaken to reduce CO_2 emissions is the popularization of clean energy vehicles (CEVs), which are more eco-friendly than existing vehicles such as gasoline vehicles (GVs), diesel vehicles (DVs), and natural gas vehicles (NGVs). The term “CEVs” covers clean diesel vehicles (CDVs), electric vehicles (EVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCVs).

CEVs are the system which the plural stakeholders such as industries, consumers, and governments are concerned with. In particular, since CEVs use advanced technology, it becomes important to design and implement appropriate public service and public policy measures. It is for this reason that we should examine CEVs not in terms of individual products, but in the context of product-service systems (PSS), which bring together products (CEVs) and service (public service). PSS is usually defined as “product(s) and service(s) combined in a system to deliver required user functionality in a way that reduces the impact on the environment” [3] [4], showing the intimate relationship between PSS and sustainability. Thus, in order to effectively develop and introduce CEV-centered PSS, it becomes necessary to assess the sustainability of this system. In this regard, Doualle et al. [5], Sousa and Miguel [6], and Omann [7] propose that the system should be assessed according to the three dimensions of environment, economy, and society. In particular, Sousa and Miguel [6] and Omann [7] provide qualitative examples of environment, economy, and society as assessment indicators. There are significant advantages of assessing

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CEV-centered PSS according to the three sustainability aspects of environment, economy, and society. In brief, because CEVs have different parts structures compared with GVs, the diffusion of each type of CEV will affect Japan's economy, society, and environment through supply chains that are different from those for GVs. For example, when comparing GVs with EVs, EVs do not need conventional GV parts such as engine parts, spark plugs, and starter motors, whereas they need a new range of parts, such as batteries and invertors. Consequently, sales of EVs will generate production, employment, and CO_2 emissions not only in the automotive industry, but also in other industries such as the battery industry. In addition, each industry for which demand is generated by the adoption of CEVs includes both labor-intensive and capital-intensive firms. Therefore, the extent to which employment is created depends on the supply chain characteristics of each CEV. The automotive industry employs approximately 9% of manufacturing workers in Japan; thus, the above-mentioned changes in the parts structure of motor vehicles will probably have a significant effect on employment. Thus, it is important to quantitatively assess the impacts of the popularization of CEVs on systems from the standpoints of economic, social, and environmental sustainability. Also, based on the result, it is important to design and implement public service and public policy measures.

Among existing studies on the ripple effect caused by the increase in the usage of CEVs, Chua et al. [8] and our previous research [9] calculated the extent of production-induced effects. Although Chua et al. [8] evaluated changes in production-induced effects resulting from the production of passenger-type EVs in Singapore, their analysis omitted other types of CEVs, as well as trucks and buses. Furthermore, they did not analyze the impacts on employment caused by the introduction of CEVs. Our previous research [9] estimated the amount of production that would be induced in Japan if the sales-volume targets of CEVs assumed by the Ministry of the Environment were met. For that purpose, they created an input-output table that included departments for each CEV type in passenger vehicles, trucks, and buses. Although our previous research [9] calculated the ripple effects on the overall economy and each industry, it did not consider impacts on the employment numbers and CO_2 emissions caused by the popularization of CEVs.

Next, Nonaka and Nakano [10] [11], and other studies [12] [13] [14] focused on the environmental effects of CEVs, particularly CO_2 emissions and energy consumption. Additionally, Schulte and Voß [15] assessed the CO_2 emissions of car-sharing systems that use environment-friendly vehicles. However, these studies did not analyze production-induced effects in industry and impacts on employment numbers caused by the popularization of CEVs.

In the light of the above, this study presents a quantitative assessment of the social sustainability of PSS that are centered on CEVs and public service. It also evaluates and analyzes how the diffusion of CEVs affects employment across life cycle in order to assist corporate product plans for CEVs along with governmental policies for promoting CEVs.

This study designates an area of Japan for a case study and covers 24 types of vehicles including GVs, DVs, CDVs, NGVs, EVs, HEVs, PHEVs, and FCVs in the form of passenger vehicles, trucks, and buses.

The rest of the study is divided into the following sections. Section 2 explains our research methodology and the various scenarios investigated. Section 3 presents the results of our analysis obtained via this methodology. Section 4 summarizes our findings and identifies tasks for future research.

2. Research methods

2.1. Evaluation model of employment effects

As indicated in the previous section, this study estimates the employment effects of the popularization of CEVs. In formulating the evaluation model demonstrated below in equation (1), this study defines employment effects as the number of jobs created by the popularization of CEVs. These employment effects are calculated by multiplying three factors: the employment coefficient, the Leontief inverse matrix, and the direct effects. The Leontief inverse matrix represents "the sum of direct and indirect spillovers generated in each industry by the consumption of one unit of a final good" [16]. Here, direct effects correspond to newly created demand in a given industry. These direct effects are evaluated based on three perspectives—the costs of production, fuel, and the construction of service stations—for each vehicle type in this study.

$$f_k(x_{ik}, s_{ik}) = E\{I - (I - M_k)A_k\}^{-1} D_{ik} \qquad (1)$$

i: Type of vehicles [passenger vehicles (GV, DV, CDV, NGV, EV, HEV, PHEV, FCV), trucks (GV, DV, CDV, NGV, EV, HEV, PHEV, FCV), buses (GV, DV, CDV, NGV, EV, HEV, PHEV, FCV)]
k: Target year
f_k: Employment effects in year k [Unit]
x_{ik}: New sales of vehicle type i in year k [Unit]
s_{ik}: The number of vehicles of type i owned in year k [Unit]
E: Coefficient table of employment
I: Identity matrix
M_k: Imports matrix in year k
A_k: Input coefficient table in year k
D_{ik}: Direct effects of vehicle type i in year k [Yen]

This study uses an input-output table to estimate the employment effects throughout the whole supply chain created by the increase in the usage of CEVs. The input-output table is a statistical table that adds up and classifies cross-industry transactions of goods and services in the domestic economy over an identified period (normally one year). The columns of the table indicate the compositions of raw materials used and the gross value added in producing goods and services. The rows show the structure of the sales destinations (output destinations) of the goods and services produced.