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Title: Multi-Objective Optimization Model for Clean Energy Vehicles Using Input-Output Tables			

Abstract

The introduction of clean energy vehicles (CEVs) is expected to reduce CO_2 emissions in the transportation sector. However, because each CEV has different internal structures compared to gasoline vehicles (GV), the popularization of each CEV type provides different impacts on three dimensions: industry, consumer, and the environment.

For example, if the sales volume of electric vehicles (EVs) increases, there is a concomitant reduction in CO_2 emissions at the vehicle using phase. However, there is an important trade-off to consider: it is expected that EVs will be priced higher than GVs, increasing the financial burden on consumers. Further, around 20–30% of the auto parts used in GVs is not required in EVs. In assessing new technologies, auto manufacturers consider the impact on the existing automotive parts industry, and might exhibit a preference for models that do not compromise the status-quo in this respect.

In other words, because each CEV has its own advantages and disadvantages, popularizing only specific types of vehicles will not necessarily maximize societal utility.

Therefore, it is important to analyze the optimal portfolio of CEVs in order to design an effective policy for the introduction of CEVs.

Most previous studies have mainly focused on the environmental performance of CEVs in the running phase, failing to consider the impact on industry. In addition, previous studies on the tools and models that calculated and analyzed the industrial ripple effect, resulting from the spread of CEVs, were insufficient.

Furthermore, since CEVs is a product closely related to the social system, which includes various stakeholders, it is necessary to design the models considering stakeholder requirements.

Therefore, the aim of this study is to develop predictive models for long-term sales volumes of CEVs, considering the stakeholder requirements and ripple effect caused by the spread of CEVs.

Specifically, this paper proposes a new multi-objective optimization model of portfolio, which considers utilities across three dimensions: industry, consumer, and government (environment). In addition, by using input-output tables to evaluate the differences in the parts' structures of GVs and CEVs, this paper proposes an industrial ripple effect model that comprehensively calculates and analyzes the ripple effect on the economic, and employment aspects of the industry.

Simulation results using this industrial ripple effect model show impacts on the economy, and employment in Japan of 2020 and 2030 for the predicted sales of CEVs assumed by the Ministry of the Environment in 2010. For example, simulation results indicate that production-induced effects in Japan in 2020 are expected to increase by about 1.3 trillion yen when compared to 2010. Also, production-induced effects in Japan in 2030 are expected to decrease by about 5.1 trillion yen when compared to 2010.

Also, the simulation results using the multi-objective optimization model of portfolio show the optimal portfolios in 2030 for each dimension across all scenarios of technological innovation. For example, in the standard scenario about technological innovation, plug-in hybrid electric vehicles (PHEVs) and fuel cell vehicles account for approximately 90% of passenger vehicle unit sales when industrial utility is prioritized. In contrast, the introduction of GVs accounts for approximately 50% of sales when the utility of consumer is prioritized. Also, PHEVs play an important role particularly when the utility of government (environment) is prioritized.

Key Words
Automotive industry, Clean Energy Vehicle, Input-output analysis, Optimization, Portfolio, Supply chain, Sustainability