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Analysis on the market evolution of new energy vehicle based on population competition model

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ABSTRACT

New energy vehicles (NEVs) development has recently become China's national strategy. For NEVs, the scientific prediction of market scale is the guarantee to formulate the effective policy planning. Considering the competition and substitution phenomenon between traditional fuel vehicles (TFVs) and NEVs, we propose a system dynamics (SD) model to investigate and predict the market evolution of NEVs and TFVs in China based on the competitive Lotka-Volterra (LV) model. Furthermore, the effect mechanism of key model parameters is evaluated by sensitivity analysis. Finally, the potential environmental impacts of NEVs in China are analyzed based on the above simulation results. It shows that NEVs will continue to grow rapidly in the coming decades and will dominate in Chinese vehicle market around 2050. Government subsidies and other consumption stimulus factors are the main driving force for NEVs development in its early stages, however, along with the policy stimulus and policy influence gradually weakening, growth in later stages will rely on convenience factors and cost advantages brought by technological progress and infrastructure improvements. It is noteworthy that the national strategic planning target in 2020 can hardly be achieved under China's current policy system and market conditions. The results of sensitivity analysis reveal that the policy support and maximum market capacity show different decisive influences on the development trend of the entire automotive market. In addition, if China's relevant energy and environmental planning can be effectively implemented, the rapid expansion of NEVs will significantly reduce the environmental impact of vehicles.

1. Introduction

With the rapid development of economy and the continuous improvement of people's living standards, the number of vehicle in China has experienced a sharp growth in China during the past decade. As a consequence, this has led to rapid growth in the energy consumption and brought a series of problems and challenges to the economy and society, such as energy security and environmental issues. At present, the proportion of oil consumption for vehicles accounts for about 50% of the total oil consumption in China, and more than 70% of the newly added oil consumption is consumed by new vehicles. Furthermore, China's net oil import amounted to about 380 million tons in 2016, with the dependence degree on oil import surpassing 60%, and it will continue to increase (State Statistical Bureau of China, 2016). The high degree of dependence upon import oil presents a severe threat to China's energy resource security and economy. With the increased oil consumption in the transportation sector, tailpipe emissions of TFVs has become one of the main cause of atmospheric environmental problems such as global warming and air pollution, which contribute to climate change

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and impact human health (Kumar Pathak et al., 2016). China was responsible for nearly 30% of the world's GHG emissions in 2014, ranking the highest globally, and about 5% of China's total GHG emissions come from passenger vehicles (Hao et al., 2015). In addition, China is facing serious urban air pollution problems. The most prominent one is the haze which the vehicles are considered to be the primary source. However, with the further development of the economy and society in the future, the trend of rapid growth in the demand for vehicles will be difficult to change, and the resulting energy and environmental problems will become even more severe. Therefore, it is imperative to promote clean energy and low carbon utilization in the transportation sector.

In recent years, with the rapid development of alternative fuel technology, NEVs have received widespread attention and market penetration around the world. NEVs are vehicles that can be fueled by alternatives to traditional fossil fuels (e.g., gasoline and diesel) in part or in full. The most common ones today are different types of electric vehicles such as battery electric vehicle (BEV), hybrid electric vehicle (HEV), and fuel cell electric vehicle (FCEV) (Jansson et al., 2017). Compared with TFVs, NEVs consume less fuel and offer the potential for directly reducing greenhouse gas emissions and exhaust pollutants in the driving process (Jochem et al., 2015; Nichols et al., 2015; Nocera and Cavallaro, 2016). Developing NEVs is generally proposed as one of the most effective ways to solve the problem of energy and the environment (Sengupta and Cohan, 2017; Yang et al., 2016). It has become an important strategic emerging industry to promote sustainable development of the world economy. Many countries have put forward and implemented their own industrial planning and policies to accelerate the development of NEVs (Adnan et al., 2017).

Among various types of NEVs, BEVs offer the benefits of consuming no oil and generating zero tailpipe emissions during the driving stage. It is generally considered to be a promising option to addressing the energy security issue and reducing pollutant emissions in densely populated cities (Wu et al., 2015). Therefore, China selected BEVs as its development direction of NEVs and formulated a corresponding strategic plan to promote BEV penetration. With the vigorous promotion of the government, China has experienced an explosive growth of BEVs market in 2014 and 2015, and becomes the fastest growing country in the world (Zhang et al., 2017). Besides, China has established an ambitious target that the market scale of BEVs will reach 5 million by 2020. Therefore, the NEVs of China studied in this paper refer to BEVs.

Until now, the research of NEVs are mainly focused on the aspects such as the related industrial policies, industrial competitiveness, economic and environmental benefits and the factors influencing adoption of NEVs (Vassileva and Campillo, 2017; Wang and Dong, 2016; Bjerkan et al., 2016), while few studies are undertaken on the scale evolution of NEVs market. The evolution of market scale can directly reflect the development status and trend of the new energy automobile industry. It is not only the essential and foundation for the planning of related industries such as charging network and power grid system, but also can provide effective decision support for government and auto manufacturers to formulate and adjust policies timely. Especially, it can well cooperate with national energy and environmental planning to solve the increasingly severe energy and environmental issues more effectively.

Therefore, how to establish reasonable and effective trend prediction model for the market scale of NEV according to China's current policy system and market environment shows important practical significance on guiding the reasonable layout for related industries and realizing the healthy and orderly development of China's NEV.

2. Literature review

The development and evolution of the NEVs market is a complex, long-term and dynamic process. It is influenced by various factors such as policy, economy, technology, environment, and consumption psychology, etc. The interactive relationship between different factors is required to be considered during the dynamic forecasting (Jensen et al., 2017; Al-Alawi and Bradley, 2013; Rezvani et al., 2015). Different from the market forecasting of TFVs, since NEVs is still in the market introduction stage, its market scale is very small and lack of regularity. In particular, few sales data are available. Therefore, it is difficult to predict the evolution process of NEVs market with classic market forecasting methods.

Up to now, several methods have been proposed to forecast market scale for NEVs such as time series method, Bass diffusion model and scenario analysis method. Some time series methods such as grey system, regression model can have better prediction effect when the data of the object is not incomplete. But the prediction accuracy is usually not satisfactory when there are more influencing factors, especially for the medium and long term forecasting (Peng et al., 2015). Bass diffusion model is applicable to the early market diffusion research of new products. The analogy method based on the market diffusion scenarios of other durable goods has been adopted to estimate the parameter for NEV's Bass equation in the past studies, so it has strong subjective prejudgment and tend to be larger deviation in the prediction result (Massiani and Gohs, 2015; Ismail and Abu, 2013). Some scenario analysis methods such as elasticity coefficient and proportion method have a certain external disturbances in statistics which makes the data doesn't really reflect the actual situation (Shafiei et al., 2012). It can be seen that factors contributing to the scale evolution of NEVs are considered relatively single in most traditional methods. Less interactions between multi-factors are integrated in majority studies, and the prediction result could not effectively reflect the evolution features from the microcosmic way (Xue et al., 2015). Therefore, further improvements are needed in aspects of theoretical approach, analytical tool and prediction accuracy.

Many different factors should be considered in the dynamic forecasting of NEV market scale. These factors interact with each other and constitute a dynamic feedback system. It is difficult for traditional methods to analyze and quantify these complex relationships (Shepherd, 2014). SD is an approach to understanding the nonlinear behavior of complex systems over time using stocks, flows, internal feedback loops, table functions and time delays. It is currently being used almost throughout all fields such as business, economics and other social systems. Compared with traditional methods, SD is more scientific and effective in study of NEVs market evolution.

In addition, most of the previous studies only focused on the growth of NEVs and related influencing factors, but rarely analyzed the dynamic development process of the entire automotive market including TFVs and NEVs from an overall perspective, making the