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Incorporating stakeholders' perspectives into models of new technology diffusion: The case of fuel-cell vehicles

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Abstract

The literature on the modeling of diffusion of technologies typically uses historical data to calibrate a model. For cases where data on the diffusion of comparable technologies are not available and where high multi-sector stakes are involved, models that use more specific information may be useful. The potential transition to alternative transportation vehicle technologies and fuels, like fuel-cell vehicles and hydrogen, would be an example of such cases. We propose an integration of theoretical frameworks on the diffusion of innovations with data on stakeholders' opinions, to develop estimates of FCVs' market-share evolution. Our estimates of the time scales required for the market, particularly for the initial stages, are longer than those obtained in other studies.

1. Introduction

The extreme dependency on oil of ground transportation systems across the world – particularly in the United States – has become a weakness in national economies. It engenders environmental degradation, excessive strategic dependency on foreign oil (e.g. Ref. [1]), pernicious health effects (e.g. [2,3]), agricultural losses, and growing contributions to global warming.

These factors have, at different points in time, directed the eyes of policymakers to alternative fuels and new automobile technologies. Oil prices triggered an interest in energy efficiency in the early 1970s, poor air quality led regulatory action to promote methanol and electric vehicles in the early 1990s, and

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energy dependence and climate change are driving the interest in hybrid electric vehicles (HEVs) and hydrogen in the beginning of the 21st century. Radical transformations have proved, however, more difficult to implement than incremental improvements of standard technologies. Policy processes to move away from a gasoline were often characterized by asymmetric information (the regulated industry dominating the technical debate), regulators' limited understanding of market demand, political unwillingness to internalize externalities, and industry reluctance to depart from the status quo.

The idea of a transportation sector relying on hydrogen as its main fuel has grown since its inception, from little more than a scientific hypothesis to a tangible possibility. As an energy carrier, just like gasoline, hydrogen necessitates a technology to extract usable energy from it. The fuel cell is the technology that most efficiently does this. When used in fuel cells, hydrogen vehicles have no tailpipe emissions while at the same time offer private benefits relative to conventional internal combustion engine vehicles (ICEVs) (e.g. superior vehicle performance.) This potential dual superiority of hydrogen fuel-cell vehicles (FCVs) has made them a favorite in both policymakers and industry camps. However, whether and when the last essential technological breakthroughs will happen is still uncertain.

Whether and when FCVs will be successful in the market is still uncertain and dependent on several factors. These factors include:

a. Technological progress: Despite sustained progress, a series of technological advances are still needed to position the hydrogen–fuel cell combination as a competitive alternative to mainstream alternatives. Areas where research and development (R&D) are currently directed to include on-board hydrogen storage and fuel cell durability.
b. Technology economics: Factors like production learning, production volume, accessibility to hydrogen fuel dispensing stations, the cost of hydrogen fuel, and R&D investment will directly affect the cost of purchasing and operating FCVs. Needless to say, this cost is to be evaluated vis-à-vis the cost associated to the purchase and operation of competing vehicle technologies.
c. Consumer behavior: Ultimately, it will be the consumer who decides the fortune of FCVs in the marketplace. Not only vehicle cost will be relevant, but also perceptions about the safety of hydrogen, the value proposition of FCVs relative to gasoline vehicles, and social pressures.
d. Regulation and political agendas: While the market will decide long-term diffusion of hydrogen vehicles, the politico-regulatory environment can play a significant role in the initial stages of the diffusion process. The time scale of the diffusion process in question is longer than typical political time scales. Today, the dominant political driver behind hydrogen in the United States is energy security, in the face of spiking oil prices, an unstable Middle East, and sustained increases in oil demand from growing economies. How long this panorama will last is uncertain. Within the next decade, perceptions on the stability in the Middle East may change, internal combustion engines may become significantly more efficient thereby tempering demand, and the OPEC may exercise its power to affect oil price through adjustments in supply. These and other factors can undermine the continuity of the political commitment, necessary to realize a transition away from oil.

Given the uncertainties involved, it is of interest to gain understanding on the potential dynamics of market penetration of FCVs. The contribution of this study is to propose an integration of theoretical frameworks on the diffusion of innovations with data on stakeholders' opinions, to develop estimates of FCVs market-share evolution.