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Greening transportation fleets: Insights from a two-stage game theoretic model

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ABSTRACT

The greening of organizational transportation fleets, especially trucks and automobiles, has gained increasing attention by companies in a variety of industrial sectors. The reasons for this concern and attention are due to regulatory and competitive pressures, but also increasing costs of fossil-fuels. Surprisingly the amount of research and modeling for fleet management overall has been rather limited, with the focus on managing green vehicle investments virtually non-existent. In this study we develop a two-stage game theoretic model that helps evaluate, from both policy and organizational perspectives, the implications of greening of transportation fleets. Various parameters are evaluated including factors such as innovations in green vehicle technology, levels of service differences, cost of fuel, adjusting tax policy, regulatory compliance requirements, and adaptation costs. This evaluation provides practical insights into actions that could be considered by regulators and organizations to encourage environmental investments.

1. Introduction

Within organizations, transportation and distribution activities are major contributors to environmental degradation and resource consumption. The emissions from transportation vehicles and related organizational activities contribute to air emissions that can cause local (smog), regional (acid rain), and global (climate change) environmental implications (Calef and Goble, 2007; Orsato and Wells, 2007). In addition, energy resource consumption from transportation activities by organizations in logistics and transportation industries result in some of their largest operational expenses. Most of these deliveries and logistics activities utilize energy produced by petroleum that is a very volatile commodity whose available inventory as a natural resource is rapidly depleting (Bakhtiari, 2004; Jeffers, 1978; Meng and Bentley, 2008). As environmental concerns are increasingly attracting attention from the public, a widespread adoption of a clean-technology for delivery vehicles has been of critical importance for the practitioners in this industry.

Many alternative energy-based vehicle designs, compared to traditional internal combustion engines, exist including full electric vehicles (MacCready, 2004), hydrogen/fuel cell vehicles (Lovins and Cramer, 2004; Sperling and Ogden, 2004), internal combustion/electric hybrids (Demirdoven and Deutch, 2004), biofuels (Rostrup-Nielsen, 2005), and compressed natural gas (MacLean and Lave, 2003). Each of these technologies has their strengths and weaknesses on various dimensions such as operational performance, environmental, and economic dimensions.

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Recent significant developments in consideration and adoption of alternative energy vehicles, especially electric/internal combustion engine hybrids, have started to occur among companies in a wide variety of companies and industries. Some examples include logistics and delivery services such as UPS (Gallagher, 2007) and Fedex (Birchall, 2006); retail giant Wal-Mart (Birchall, 2006); telecommunications and utilities such as AT&T (Energy Resource, 2008) and Verizon (Wireless News, 2008); large and small beverage companies such as Coca-Cola (Cioletti, 2008), Pepsi (Deierlein, 2007) and VinLux Fine Wine (Mele, 2008); and even companies within the forestry (Fleet Equipment, 2007) and banking industries (Carr, 2007). Even though some of these companies have trucking and transportation fleets that number in the tens of thousands, most are only considering to adopt or adopting dozens of vehicles. Thus, there is ample room to grow in the adoption of these vehicles, but careful competitive, strategic and operational considerations must be made. Also, guidance, support and encouragement from policy makers and regulators may provide different environmental contexts for the adoption of these types of vehicles.

In this paper, we will investigate how external policies and internal organizational decisions play a role in these environmentally oriented investment decisions, such as greening transportation fleets for organizations, using a two stage game theoretic framework. The specific problem we consider in this paper focuses on determination of the level of hybrid or alternative energy delivery fleet for a logistics and transportation company. We construct a model of self-selection with heterogeneous consumers who value the firm's delivery service along two dimensions: the quality of delivery service and the relative reduction in emissions (a proxy for environmental performance). In this framework firms choose the adoption level and the percentage of their fleet that should be 'green', in the first stage, and the optimal level of price in the second stage. We consider an asymmetry between the firms by initially crediting high quality delivery service for one firm when compared to a competing firm with a focus on their formation choice of their fleet. This high-low delivery service quality difference is treated as an exogeneity; this situation not only reflects the fact that firms generally have different market shares in equilibrium, but it is also useful for investigation of insightful propositions which cannot be drawn from a symmetrical model.

The main contribution of this study is an in-depth examination of the role of strategic interactions between firms in terms green technology adoption. The optimal adoption rate for each firm depends on the balance between the benefits (increase in demand and reduction in fuel cost and government penalties) and the cost (increase in adaptation cost). An increase in adaptation rate also has two important countervailing strategic effects on competiveness in pricing at stage two: The first product differentiation effect will enlarge the gap between the adaptation rate, which reduces price competition at stage two; the second cost reduction effect will increase price competition.

After presenting the model and solving for equilibrium conditions, we provide some exemplary and illustrative results of the effects of the change in important organizational and policy parameters. These parameter scenario analyses provide additional insights for organizational and regulatory policy issues, which can then be used for evaluation and justification of alternative decisions facing investments in environmentally oriented transportation technology, specifically alternative energy transportation vehicles and/or technology. We conclude with an overview summary and possible extensions to this work.

2. Regulatory and organizational evaluation of environmental innovation

To exemplify some of the nuances of environmentally-oriented organizational decisions for transportation fleet management let us consider the case of FedEx, one of the leading organizations in developing and adopting an alternative energy, hybrid transportation fleet. Environmental Defense and FedEx had been collaborating to source a new generation of delivery trucks since 2000, which was expected to bring a huge improvement in fuel efficiency and pollution emission. As a reasonable course of this collaboration, FedEx joined forces with manufacturers to develop the necessary technology for its trucks and purchased a number of clean, relatively energy efficient trucks, known as hybrid delivery fleet. The multiple partnerships involved technological supporting groups, like Eaton Corporation (transmission technology) and Freightliner (chassis technology). Environmental Defense estimated that for every 10,000 conventional FedEx delivery trucks, which cause serious environmental and health damages through diesel exhaust, replaced by cleaner hybrids, pollution reduction of 2000 tons per year would occur. Moreover, diesel fuel usage would be reduced by 6.5 million gallons per year bringing significant benefits to the organization, according to the estimate. A study prepared for the Texas Council on Environmental Technology (TCET) estimated that the future price of diesel electric hybrid trucks would be 30% higher than that of the conventional ones if the production reaches to the mature stage, while the maintenance cost would be 10% lower through electric power supplements.[2] These estimated results occurred even before the costs of petroleum more than doubled in more recent years.

The decision for adoption of these types of alternative energy and hybrid vehicles may bring improved environmental performance for the benefit of society. But it is expected that this adoption contributes to additional financial burdens for organizations, in some areas, on initial investment, operational, and maintenance costs, especially over a short time span.

An organizational justification issue now arises based on these tradeoffs. What benefit could be accrued for organizations where they would be willing to adopt a short-term cost burden from this environmentally oriented investment strategy of greening their transportation fleets? This is where organizations need to make the 'business case' for these types of investment. Making the business case for environmentally sound practices is not always a trivial decision (Presley and Sarkis, 1994; Presley et al., 2007). The business case involves both operational and strategic costs and benefits that need to be

[2] Stanford Graduate School of Business, "FedEx and Environmental Defense : Building a Hybrid Delivery Fleet", Case SI-82, Jan, 2006.