An investigation of government incentive policy in green technology adoption in automobile industry

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Abstract

As the environmental awareness increases, government's green technology incentive has been identified as an effective approach to reduce carbon emissions and facilitate the environmentally friendly agenda. To date, little is known in the literature about the relationship between government's green technology-dependent incentives and supply chain behaviors. Thus this research aims to address this research deficit by investigating the decision making in supply chain given green incentives. Mathematical modeling approach is used to analyze the interaction between government and supply chain parties. Findings of this research provide managerial implications to supply chain management practitioners and practical suggestions to government policy-makers.

Keyword: Incentive policy, Supply chain management, Green technology

Introduction and related work

In response to the rise of environmental awareness, governments are seen to roll out a variety of green interventions in dealing with Green House Gas (GHG) emission (Cohen et al., 2015). Due to the immense fuel consumption and GHG emission in transportation (EPA of US, 2014), automobile industry is often put under the spotlight when seeking to reduce the GHG emission in many countries (Gnann et al., 2015). As a

result, the adoption of green vehicles in the automobile industry is advocated and believed to be an effective way to reduce the GHG emission (Mak et al., 2013). In fact, an increasing number of car manufacturers are seen to invest in green technology in an attempt to improve the fuel efficiency and greenness of their vehicles (Xu et al., 2013). It is believed that their actions are as a result of the integration of not only the economical, but also the environmental, considerations into their operation strategies (Dahlsrud, 2008). Incentive policy is recognized by many scholars as an effective approach to control GHG emission (Chappin et al., 2009; Coria, 2009; Dowson et al., 2012). In today's car industry, the government incentives prove to have a significant impact on green technology adoption in hybrid vehicles (Diamond, 2009) and emission reduction by transportation (Cohen et al., 2015). In spite of this, little is known about the relationship between government's green incentives and the decision making in supply chain. Hence, this study aims to examine the influence of government green incentives from a supply chain's viewpoint, and to provide implications to government green policy makers.

For government, in order to effectively reduce carbon emission, it is important to drive green technology adoption in car industry, which requires effective allocation of government incentives in the industry (Goulder & Mathai, 2000). Government incentive is seen as an investment, which aims to achieve a better environmental performance and increase the society's welfare. The welfare resulted from government incentives is seen as the return of the investment. The provision of government incentives not only can drive supply chain's green technology innovation in car industry, but also may bring benefits to consumers, which is considered as the return of government incentives. To make a good green policy, the policy maker ought to allocate government resources in a way to maximize the efficiency of government incentives (Goulder & Mathai, 2000). On the other hand, supply chain decisions are also affected by the external market environmental factors. For example, car consumers have preferences towards the green technology (Pickett-Baker and Ozaki, 2008), and tend to buy cars with lower emission level (Daziano & Bolduc, 2013). Car consumers may also be price sensitive. For instance, consumers are more sensitive to the price in response to economic depression. Hence, this research investigates the supply chain behaviour in response to the government's incentive taking into consideration of the uncertainty in consumer green technology preferences and price sensitivity, which have not been considered in the extant literature.

Krass et al. (2013) proposed a mathematical model to investigate the green policy

and the choice of green technology. They used the social welfare as government's objective, which is common in the existing literature (Baldwin & Krugman, 2004; Boskin & Sheshinski, 1978; Krass et al., 2013). Social welfare is the sum of a company's profit and consumer surplus minus the environmental impact (Krass et al., 2013). This paper applied Krass et al. (2013)'s regulator's social welfare objective function and Fischer et al. (2003)'s incentive welfare function as the foundation to construct government's objective. It is assumed that government's objective is to maximize the welfare resulted from government incentives (Boskin & Sheshinski, 1978), while maintain a balance between environmental impact, supply chain profit, and consumers' benefits. In summary, this paper seeks to understand the relationship between the government green policy for car industry and the decision-making in supply chain. In doing so, we first examined the influence of government green incentives on green technology adoption and pricing decisions. Then, we built an incentive model to investigate the supply chain behavior in response to the given government green incentives. The influence of incentive is observed via the concept of sustainability. It was indicated that the concept of sustainability is built on the foundation of the triple bottom-line (Jamali, 2006), in which a balance between profits, people and environment is sought to be achieved. Thus, in this paper, the influence of incentives is examined along the 3P-dimensions (Fisk, 2010). By examining different scenarios in the model, the managerial implications for strategic policymaking are implied, and suggestions for supply chain management are also illustrated.

Methodology

This paper illustrates the decision making by government and supply chain parties using a mix-method approach. First, a game model was built to demonstrate the decision making by supply chain parties. Game theory is frequently used to solve strategy-related supply chain problems (Nagarajan & Sošić, 2008) and green technology and emissions related issues in supply chain management (Lukas & Welling, 2014; Du et al., 2015). Therefore, this paper adopted game model to describe and analyze the interactions between decision-makers on the basis of the work of Leng and Parlar (2005). Second, qualitative data was used to connect the game model to simulation process and build the foundation for the simulation model. 11 practitioners from automobile industry in Taiwan were interviewed in order to adjust and/or confirm the detail components of decision-making process in the incentive model. Third, we aimed to examine the

performance of government incentives in supply chain. Thus we also employed the simulation method as it is a suitable technique to analyze performance in supply chain (Jansen et al., 2001). It is thought that the integration of simulation and optimization approach can effectively increase the efficiency of analyzing continuous decision variables (Wan et al., 2005). In addition, the optimization of game model between the supplier and the manufacturer was also considered in the simulation process. The uncertainties of pricing and green technology preference sensitivities were revealed by qualitative data, and thus Monte Carlo simulation method was used in this paper to capture the supply chain behaviors in response to the government green technology incentives.

Model Notations

T_s : The green technology level of the supplier

T_m : The green technology level of the manufacturer

w : The per-unit wholesale price charged to manufacturer by supplier

p : The price of the product in the market

G_s : Incentive per unit of green technology offered to the supplier

G_m : Incentive per unit of green technology offered to the manufacturer

Q : Market Demand

a : Market size

b : The sensitivity of market price's influence on the demand function

c : The factor/sensitivity of the product greenness in the demand function

α : The weight of supplier's green technology level's influence on product final greenness

β : The weight of manufacturer's green technology level's influence on product final greenness

C_f : The marginal fixed cost of improving green technology for the supplier

C_d : The marginal fixed cost of improving green technology for the manufacturer

C_s : The variable production cost for the supplier

C_m: The variable manufacturing cost for the manufacturer

R_s : Government green technology review for supplier

R_m : Government green technology review for manufacturer

ε_s : The factor of government's green technology review on incentive adjustment for supplier

ε_m : The factor of government's green technology review results on incentive adjustment for manufacturer

π_s : Profit of supplier

π_m : Profit of manufacturer

Supply chain objective functions

The model describes the interaction between supplier and manufacture given government's incentives. The incentive rates are green technology level dependent and adjusted every period based on the review of last period. It is assumed the objectives of supplier and manufacturer are both profit maximization which presented in equation (1) and (2).

Equation (1): Supplier's objective function
Max.

$$\pi_{s_t}\left(w_t, T_{s_t}\right) = \left(w_t - T_{s_t} C_s (1 - G_{s_t})\right)\left(a - bp_t + c\left(\alpha T_{s_t} + \beta T_{m_t}\right)\right) - (T_{s_t} - T_{s_{t-1}})^2 C_f (1 - G_{s_t})$$

Subject to

$$w_t \geq 0$$

$$T_{s_t} \geq 0$$

$$a - bp_t + c\left(\alpha T_{s_t} + \beta T_{m_t}\right) \geq 0$$

Equation (2): Manufacturer's objective function
Max.

$$\pi_{m_t}\left(p_t, T_{m_t}\right) = \left(p_t - w_t - T_{m_t} C_m (1 - G_{m_t})\right)\left(a - bp_t + c\left(\alpha T_{s_t} + \beta T_{m_t}\right)\right) - (T_{m_t} - T_{m_{t-1}})^2 C_d (1 - G_{m_t})$$

Subject to

$$p_t \geq 0$$

$$T_{m_t} \geq 0$$

$$a - bp_t + c\left(\alpha T_{s_t} + \beta T_{m_t}\right) \geq 0$$

Mechanism of government incentive giving

According to the collected qualitative data, this paper also modeled the incentive giving in supply chain. The incentive is given by a percentage of supply chain's variable cost and fixed cost. That is, for supply chain parties', the cost of green technology investment is expected to be partially covered by the government incentives. However, government changes the incentive rates based on the performance of green technology improvement, because the aim of green incentives policy is to increase the green technology levels in supply chain. Government green technology review and incentive rate adjustment is demonstrated as equation (3) and (4).

Equation (3): Incentive adjustment for supplier and manufacturer

$$\mathrm{Rs}_t = \varepsilon_s * (Ts_t - Ts_{t-1})$$

$$\mathrm{Rm}_t = \varepsilon_m * (Tm_t - Tm_{t-1})$$

Subject to,

$\mathrm{R}i_t = [-1,1]$, for t = 1,…, N, i= s, m

Equation (4): The incentive rate for supplier and manufacturer at period t+1

$$G_{s_{t+1}} = G_{s_t} + \mathrm{R}_{\mathrm{s}_t} = G_{s_t} + [\varepsilon_s * (Ts_t - Ts_{t-1})]$$

$0 \leq Gs_{t+1} \leq 1$, for t = 0, …, N

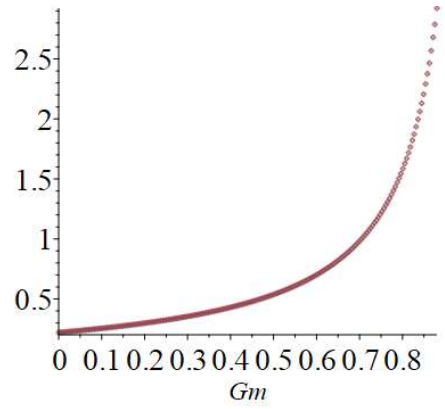
$$G_{m_{t+1}} = G_{m_t} + \mathrm{R}_{\mathrm{m}_t} = G_{m_t} + [\varepsilon_m * (Tm_t - Tm_{t-1})]$$

$0 \leq Gm_{t+1} \leq 1$, for t = 0, …, N

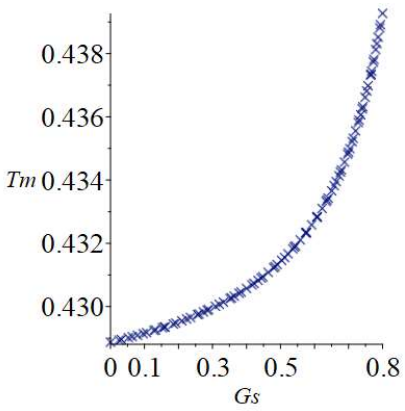
Findings

The results of the model show a positive effect from supplier's and manufacturer's incentives on green technology level (figure 1). Incentives not only affect technology decisions, but also lower the product price as manufacturer's decision in the model. The more incentives received by either the supplier or the manufacturer, lower the price offered to the market is. For supplier's pricing decision, the relationship between supplier's price and supply chain incentive rate is illustrated in figure 2. It was found that supplier attempted to lower the price when manufacturer received higher incentive rate. However, the supplier's incentive rate did not have a significant and direct effect on

supplier's pricing decision. In this model, there was an interaction between the supplier and the manufacturer as shown in figure 3 and 4. Overall, manufacturer had higher green technology level when receiving more incentives. However, manufacture's green technology level decreased at a point when supplier gained high incentive rate. This phenomenon remained unless both supplier and manufacturer had high incentive rates. The decision-makings of manufacture's and supplier's were mutually influenced. Supplier's green technology level increased when receiving more incentives. However the incentives had a negative effect on supplier's green technology level when both supplier and manufacturer had received high incentive rates (figure 4).



The impact of Manufacturer's incentive rate on Manufacturer's green technology



The impact of Supplier's incentive rate on Manufacturer's green technology

Figure 1 — The influence of incentive rate of supply chain parties on manufacture's green technology level

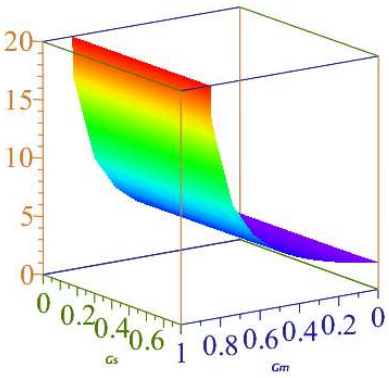


Figure 2 — The impact of Supplier and Manufacturer's incentive rates on Supplier's price

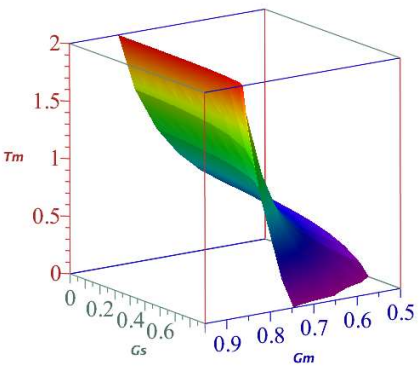


Figure 3 — The impact of Supplier and Manufacturer's incentive rates on Manufacturer's green technology level

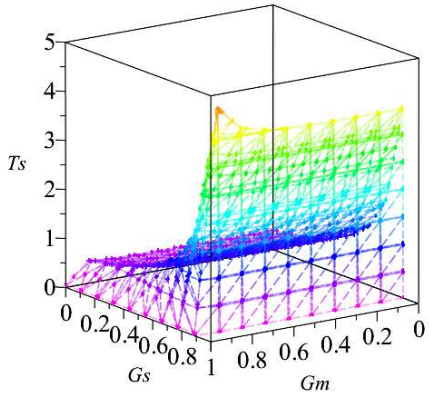


Figure 4 — The impact of Supplier and Manufacturer's incentive rates on Supplier's green technology level

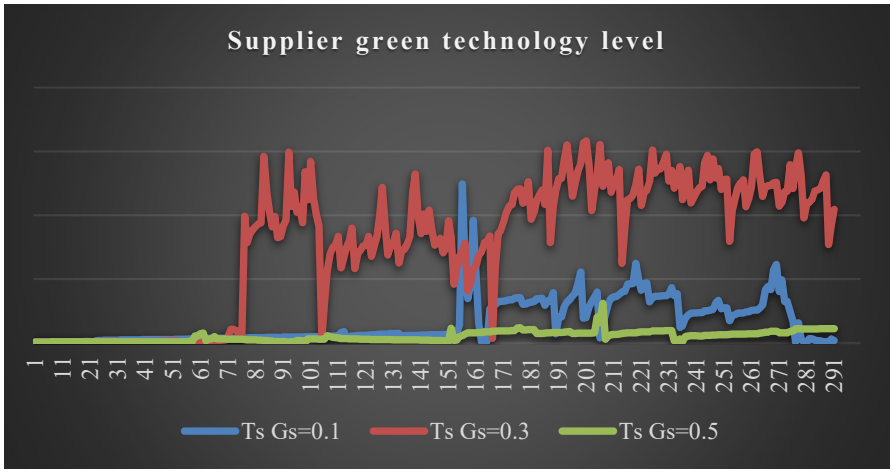


Figure 5 —Manufacturer green technology level under different incentive rates on Supplier

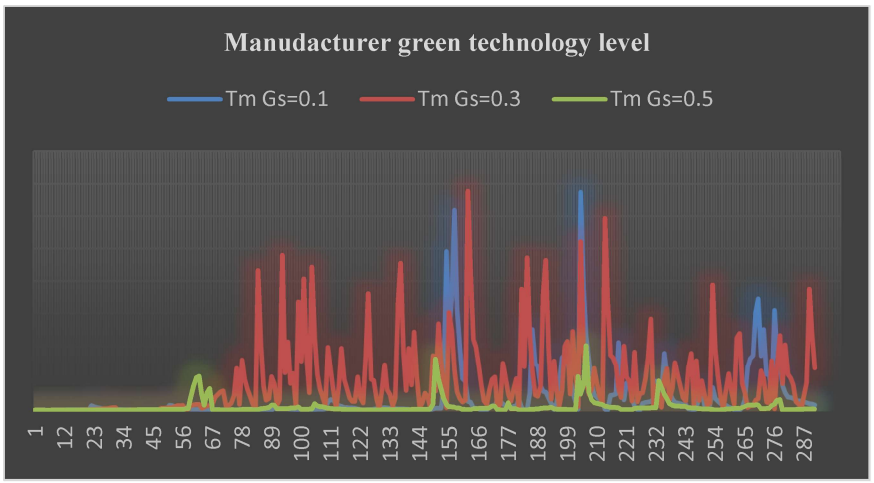


Figure 6 —Supplier green technology level under different incentive rates on Supplier

Conclusion and discussion

This paper demonstrates the influence of incentives on supply chain's decision making and provides insight to supply chain management and government green policy making. It suggests that supply chain parties should consider not only their own's incentive rates but also other's incentive rates when making pricing and green technology decisions. This paper also proposes that government should provide a medium to low incentive rate to supply chain parties (see figure 5 and 6), because the positive benefit from green incentive reduces when the initial incentive rate incentive rate is too high or too low. Findings of this paper suggests that government should identify the appropriate initial incentive rates in response to marketing environment, and allocates its resources reasonably and efficiently.

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