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Optimal New Energy Vehicle Production Strategy Considering Subsidy and Shortage Cost

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Abstract

In this paper, we present an analytical model to investigate how the optimal production strategy of new energy vehicles (NEVs) is influenced by subsidy, market fluctuation, and loss aversion. We find that a loss averse decision maker may produce more production quantity than the optimal quantity in risk neutrality under the certain conditions. We demonstrate that the expected utility is substantially influenced by subsidy, loss aversion, and the shortage cost. Although the relationship between subsidy and loss aversion is not straightforward when considering shortage cost, subsidy may play a role to regulate the possible overages and shortages in NEV manufacturing. Implications to both policy makers and practitioners are discussed.

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Keywords: new energy vehicle, shortage cost, loss aversion, subsidy, newsvendor model

1. Introduction

The market for new energy vehicle (NEV) in China becomes booming. NEV refers to electric vehicle, fuel cell battery vehicle, and plug-in hybrid electric vehicle. In the first ten months of 2014, a total of 46,935 NEVs have been produced[1]. And a total of 38,163 NEVs have been sold in the first nine months[2], surging by 2.8 times compared to the total sales volume in the same period of 2013. A series of major factors contribute to the NEV market growth, including the extension of the subsidy program for NEV manufacturers with a gradual reduction beyond 2015, the purchase tax exemption for consumers, more NEV models and types available on the market, the restrictions on fuel oil vehicles, and the

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advancement of technology (such as the increased battery capacity with a greater cruising range etc.), to name a few.

The recent surge in NEV demand reminds the managers to consider the possible influence of stockout problem. In fact, the media has already reported the battery supply shortage which in turn causes the shortage of NEV supply[3]. In addition to the market fluctuation, managers of NEV manufacturer have to consider a number of other influential factors when making production decision, including subsidy and decision bias. On one side, subsidy drives down the relatively high selling price to make the NEV more economically competitive. On the other side, the manager's decision making behavior is governed by human behavioral and psychological rules, such as loss aversion[4][5][6][7][8][9], which may cause decision bias. The decision bias further complicates the decision process as it brings another uncertainty when predicting the influences of government incentives on promoting NEV production and adoption.

In this paper, we investigate the loss averse NEV manager's decision making process with overage risk, underage risk, and subsidy. The analytical work is based on the loss averse newsvendor model (see [10] and [11] for reviews of the risk neutral newsvendor model). Due to the different research focuses, previous studies on loss averse newsvendor model assume that the unsatisfied demand is lost, see for example [12][13][14][15]. In this paper, we show how the shortage cost substantially influences on the manager's optimal quantity and the effect of subsidy. We also reveal the interaction mechanism among subsidy, loss aversion, the optimal production quantity, and the expected utility. In the following, we present the analytical model with shortage cost in Section 2. In Section 3, we derive the optimal solution and the relevant properties of the proposed model. We discuss the results and make concluding remarks in Section 4.

2. The analytical model

Consider a situation where a manager of a NEV manufacturer facing stochastic demand, x, with the probability density function $f(x)$ and the cumulative distribution function $F(x)$. The manager has to decide how many NEVs to produce well in advance before the selling season starts. Let p be the per unit selling price of the product, c the per unit production cost, s the per unit salvage value, and g the per unit goodwill cost due to shortage, $s > 0$, $g > 0$. Let Y be subsidy to NEV manufacturer, $Y > 0$. Following [9], we assume the NEV manager knows that his company receives the per unit subsidy Y for the realized demand, indicating that each product has a higher per unit revenue $(p + Y)$. Different from [9], we incorporate the shortage cost here. The profit function $\pi(Q, x)$ can be written as follows:

$$\pi(Q,x)=\begin{cases}(p+Y)x+s(Q-x)-cQ & \text{if } x\le Q\text{, the overage situation}\\ (p+Y)Q-g(x-Q)-cQ & \text{if } x>Q\text{, the underage situation}\end{cases} \tag{1}$$

From the profit function (1), the manager knows that there are two breakeven points. Let q_o and q_s be the breakeven quantities corresponding to the overage and the shortage cases, respectively. The q_o and q_s can be written in the following manners:

$$q_o(Q)=\frac{(c-s)Q}{p+Y-s} \tag{2}$$

$$q_s(Q)=\frac{(p+Y+g-c)Q}{g} \tag{3}$$

When the demand is less than q_o or more than q_s, the manager knows that the profit is below the relevant breakeven points, and hence is negative. According to loss aversion theory[4][6], the manager in