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Qualifying for a government's scrappage program to stimulate consumers' trade-in transactions? Analysis of an automobile supply chain involving a manufacturer and a retailer ☆

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ABSTRACT

We investigate an automobile supply chain where a manufacturer and a retailer serve a market with a fuel-efficient automobile under a scrappage program by the government. The program awards a subsidy to each consumer who trades in his or her used automobile with a new fuel-efficient automobile, if the manufacturer's suggested retail price (MSRP) for the new one does not exceed a cutoff level. We derive the conditions assuring that the manufacturer has an incentive to qualify for the program, and find that when the cutoff level is low, the manufacturer may be unwilling to qualify for the program even if the subsidy is high. We also show that when the manufacturer qualifies for the program, increasing the MSRP cutoff level would raise the manufacturer's expected profit but may decrease the expected sales. A moderate cutoff level can maximize the effectiveness of the program in stimulating the sales of fuel-efficient automobiles, whereas a sufficiently high cutoff level can result in the largest profit for the manufacturer. The retailer's profit always increases when the manufacturer chooses to qualify for the program. Furthermore, we compute the government's optimal MSRP cutoff level and subsidy for a given sales target, and find that as the program budget increases, the government should raise the subsidy but reduce the MSRP cutoff level to maximize sales.

1. Introduction

In recent years many scrappage programs have been implemented to encourage the trade-in of old automobiles with more fuel-efficient new automobiles. Such programs generally have the dual aim of stimulating the automobile market and removing inefficient, high-emission automobiles from the road for the purpose of environmental protection. Even though some governments introduced similar programs (e.g., tax rebate programs) in the 1990s, the scrappage program was widely adopted in a number of countries only during the global recession that began in 2008. This happened because the 2008 financial storm heavily influenced the world-wide automobile sector, resulting in an unprecedented automobile industry crisis.

In Table 1, we provide a summary of automobile scrappage programs that have been implemented by the governments of eight countries or regions in Asia, Europe, and North America. Under a scrappage program for automobile, a *contingent* subsidy is provided to each consumer who trades in his or her old vehicle for a new, more *fuel-efficient* one that has a combined fuel economy.

Some governments (e.g., Hong Kong, the United States, etc.) have reported that the scrappage program is useful for stimulating the sales of fuel-efficient vehicles. For example, the Environmental Protection Department of Hong Kong prepared HK$3.2 billion for its scrappage program, and announced that this amount had been committed within 18 months. As reported by Yacobucci and Canis (2009), the United States appropriated an initial amount of $1 billion for its "Car Allowance Rebate System" (CARS) program to support qualifying transactions. Immediately after the first week of implementing the CARS program, the United States's Department of Transportation announced that this program was embraced by thousands of consumers and by automobile retailers across the country, and nearly all of the funds appropriated for the CARS program were committed. In a response to the high demand resulting

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Table 1
A summary of scrappage programs that have been implemented by the governments of eight countries or regions in Asia, Europe, and North America.

Country/Region	Scrappage program for automobile trade-in
China (Chinaautoweb.Com, 2010)	The government provided each consumer with a subsidy of RMB3000–RMB6000 for trading in a used, heavy polluting car or truck with a new one since June 2009, and later increased the subsidy to RMB5000–RMB18,000 in order to implement the program more effectively
France (IHS Global Insight, 2010)	Each consumer can claim a €1000 subsidy from the government if he or she trades in a used car that is more than 10 years old with a new car that meets Euro IV emission standards
Germany (IHS Global Insight, 2010)	The government offers a €2500 subsidy (with a total subsidy value of €1.5 billion) to consumers who trade in their old vehicles for new ones that have low carbon dioxide emissions
Greece (IHS Global Insight, 2010)	The government offers the subsidy of €1900–€4200 to each buyer who trades in his or her old car with a new one that has ecological credentials
Japan (Yacobucci & Canis, 2009)	The government provides a subsidy of JPY250,000 for the trade-in of each vehicle first registered 13 years ago or earlier with a new model compliant with 2010 fuel efficiency standards
Mexico (Niedermeyer, 2009)	The federal government provides a 15,000 pesos subsidy to each consumer who replaces his or her vehicle that is at least 10 years old with a new, fuel-efficient one, if the manufacturer's suggested retail price (MSRP) for the new vehicle is less than or equal to 160,000 pesos
Slovaks (IHS Global Insight, 2010)	The government provides a €1000 state subsidy to each buyer who replaces a car that is more than 10 years old with a new one, if the MSRP for the new car is not greater than €25,000
The United States (Yacobucci & Canis, 2009)	The US president recently signed the "Consumer Assistance to Recycle and Save" (CARS) act. Under this act, if the MSRP for a new automobile is not greater than US$45,000, then the government rewards each consumer with a subsidy of US$3500 or US$4500, which depends on the types of both the new and the old automobiles

from the CARS program, the House of Representatives decided to make available an additional $2 billion to extend the program. In Slovaks, 62.3% of the total sales realized between March and December 2009 were attributed to the government's scrappage program; see the IHS Global Insight (2010).

From our above discussion, we find that the scrappage program can be effective in stimulating sales for fuel-efficient automobiles during the economic recession. Hence, it would be important, and interesting, to consider the following relevant questions. First, we need to investigate if the manufacturer's and the retailer's profits when the manufacturer qualifies for the scrappage program are higher than those when the manufacturer does not qualify. We note that the government's target of implementing the scrappage program is to boost the sales of fuel-efficient automobiles for the purpose of reducing harmful emissions and protecting the environment. Accordingly, we examine the conditions under which the program can effectively stimulate the sales. We find from Table 1 that some governments (e.g., Mexico, Slovaks, and the United States) provide their subsidies only to the buyers who purchase new cars each with a manufacturer's suggested retail price (MSRP) no more than a pre-determined cutoff level, whereas other governments (e.g., China, France, Germany, and Japan) do not set any MSRP cutoff level for their scrappage programs. It thus behooves us to investigate the impact of the MSRP cutoff level and the subsidy amount on the automobile sales. To address our above questions in a *general* setting, we assume in this paper that the scrappage program for automobile trade-in involves a cutoff level and a subsidy.

We consider a two-echelon supply chain where a manufacturer and a retailer serve consumers with a fuel-efficient automobile under a government's scrappage program. The manufacturer makes a wholesale pricing decision and, as in the *real-world* automobile industry (see, e.g., Leaseguide.com, 2011), determines an MSRP as a markup above the wholesale price. In accordance with the practice, the MSRP can be calculated as the manufacturer's wholesale price plus a markup percentage of the wholesale price. The markup percentage for an automobile *uniquely* corresponds to a gross profit margin, which, in the past two decades, was *usually* between 4% and 13% with an average value in the range [6%,8%], as indicated at Leaseguide.com (2011).

The retailer purchases the manufacturer's automobiles at the wholesale price, and then serves heterogenous consumers in a market of a finite size. That is, there are a certain, finite number of consumers each having a net valuation which is the consumer's valuation of a new, fuel-efficient automobile minus the valuation of his or her old automobile. To reflect the heterogeneity, we characterize the consumers' net valuations by a non-negative, finite-valued random variable. As in practice, the retail price for each consumer is determined as a discount of the MSRP, which results from the negotiation between the consumer and the retailer. Accordingly, we analyze the bargaining process to determine the discount of the MSRP and calculate the retail price for each consumer. Since the retailer and the consumer may have different bargaining powers, we apply the generalized Nash bargaining (GNB) scheme—which was developed by Roth (1979)—to analyze the two-player cooperative game and find a unique MSRP discount, which determines the retail price charged to the consumer. For a recent application of GNB in supply chain analysis, see Huang, Leng, Liang, and Liu (2013), who performed a numerical study to analyze automobile supply chains under a subsidy scheme, and Luo, Leng, Huang, and Liang (2014), who analytically investigated a price-discount scheme for an automobile supply chain.

We then use the negotiated retail prices to develop the manufacturer's profit function, and maximize it to find the manufacturer's unique optimal wholesale price under a scrappage program. We derive the condition under which the manufacturer can benefit from the program and is thus willing to set an MSRP lower than or equal to the cutoff level and qualify for the program. In addition, we show that, when the manufacturer qualifies for the scrappage program, raising the MSRP cutoff level will result in an increase in the manufacturer's expected profit but a decrease in the expected sales. Therefore, if the government intends to increase the expected sales for the fuel-efficient automobile, then it should set a moderate value for the MSRP cutoff level. In addition, we find that a small subsidy may be ineffective in stimulating the sales. The government's optimal subsidy is increasing in its budget, while its optimal MSRP cutoff level is decreasing in the budget.

2. Literature review

This paper is related to two streams of literature. The first stream explores the trade-in subsidies provided by firms. For example, Levinthal and Purohit (1989) investigated a firm's trade-in scheme for its durable products, and showed that the firm can utilize trade-in rebates to promote an improved product generation by deterring the secondary market. For the trade-in problem by Levinthal and Purohit (1989) and Ackere and Reyniers (1995) found that trade-in rebates can encourage consumers to trade in their used products for new ones. Fudenberg and Tirole (1998) considered the optimal pricing and trade-in rebate