

Durable Goods Leasing in the Presence of Exporting Used Products to an International Secondary Market

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Abstract

With the rapid growth of global trade, used durable goods from wealthy countries increasingly find their way into the secondary market of less wealthy countries. Exporting used products to a physically separate market not only removes cannibalization for new products at home, but also fetches additional revenue.

In this paper, we investigate the implications of exporting used products to international secondary markets in the durable goods industry. We find that such a practice may significantly stimulate new product lease on the home market, an effect in which the market attractiveness and product quality are mutually reinforcing. We discover that removing cannibalization pressure is more of a priority than generating additional revenue while exporting used products.

If the export is carried out by an agent, which exports used products bought from OEM (Original Equipment Manufacturer), we observe the disadvantage of double marginalization in a channel structure, which slows down export and causes quantity distortion, and also reduces the effectiveness of government stimulus. However, if the market is perfect and the agent has equal power as OEM, this reduces the quantity distortion.

One special characteristic of used products trade across borders is the involvement of governments on both sides of the border. The government measures include penalties imposed on aging durable goods and trade barriers. We find that legislation of penalizing used products on the domestic market can stimulate export, but it does not have an intended effect of stimulating new products produced at home. The channel structure worsens the problem.

Keywords: Durable Goods, Product Leasing, International Secondary Market, Vertical Differentiation, Channel Structure, Government Stimulus.

1 Introduction

As one of the countries worst hit by recent financial crisis, Hungary saw new cars sales plummet from 153,346 in 2008 to 60,189 in 2009 and further to 43,396 in 2010. For such a small country with only 10 million people, this sharp decline has immediate and visible consequences on the country's fleet: the average age of cars in Hungary has increased from 10.45 years in 2008 to 12.43 in 2012, and there is a sharp decline in number of used cars available for sale on the used car market since the new cars sold in 2008-2010 became used cars today. Simultaneously, the demand for used cars in Hungary has increased since fewer people can now afford to buy new cars as the economy slowly recovers. The simultaneous increase in demand and fall in domestic supply of used cars have given rise to an import of used cars from foreign countries into Hungary, which increased from 17,000 in 2010 to 70,000 in 2013. Unsurprisingly, the majority of them are from Germany, a prosperous neighbor and also the leading automobile manufacturer and market in Europe. German Original Equipment Manufacturers (OEMs) have taken a very proactive role in this cross-border transaction of used cars. For example, BMW leases new cars to its employees and car rental companies in Germany; the leased cars with low mileage (less than 15,000 km) and young age (less than one year) are then exported outside Germany to emerging markets of Eastern Europe, such as Hungary, through the program BMW Premium Selection (www.bmw.hu/premiumselection). Similar programs also exist for other German OEMs, such as the Weltauto program of Volkswagen group (Audi, VW, Skoda) and Jahreswagen program of Mercedes-Benz.

The cross-border trade of used cars can be seen in many parts of the world, although details vary from case-to-case due to different local conditions. Used cars from Japan can be found in almost all parts of the world, and the Toyota Hilux pick-up truck with a machine gun on top is commonly seen in military conflicts in the Middle East. Many used Japanese cars enter the neighbouring Far Eastern part of Russia, where 60% of cars on the street of Vladivostok are right-handed and the car import business provides employment for tens of thousands of locals. The used car trade between Japan and Russia is very different from the one between Germany and Hungary in two important aspects. First, related legislation of both governments play an important role in the trade. In Japan, drivers are required by law to submit three-year-old cars to strict road tests costing at least \$1250 – with subsequent tests every two years. It is equally expensive to dispose of them too. This makes aging cars worth very little, and owners normally relinquish ownership before it gets too expensive. This essentially pushes used cars out of Japan. The Russian government also introduced an ever-increasing tariff to curb the inflow of used Japanese car imports, largely to protect local automobile manufacturers, such as Lada. Second, unlike their German counterparts, OEMs in Japan are not directly involved in the exporting business. Instead, there are thousands of agents specialized in the cross-border trade of used cars, such as JAA, JU Group, TAA, USS, and ZIP, who would collect used cars from OEMs mostly through the method of auctions and then export the cars to foreign countries.

The cross-border trade of used cars has rather important implications for management. First, removing used products from the home market makes cannibalization between new and used products less of a concern, which has been a central theme in the durable goods literature. Second, since new products are needed as the source of used products, the additional demand from the foreign market for used cars provide a new stimulus for new product sales. Third, there are multiple actors involved in the cross-border trade, such as the governments on both sides of the border, import/export agents as middlemen, and low-cost competitors at foreign market; their presence makes the story much more interesting.

In this paper, we seek to answer 3 questions:

1. With an active international secondary market to sell used products returned after lease, how should the firm adjust its production and pricing?
2. With additional players, such as export agents, how would the additional complexity of channel structure change the problem?
3. If legislators wish to achieve a certain social goal, such as simulate production or protect local industry in the presence of this cross-border trade, what are the most effective and efficient tools?

The remainder of the paper is organized as follows. Section 2 reviews related literature. Section 3 introduces the model set-up. Section 4 analyzes the monopoly case. Section 5 studies impact of third party collectors. Section 6 concludes the paper.

2 Related Literature

Durable goods have received ongoing attention in marketing and economics literature, and much of the focus has been on comparing leasing and selling options. Mantena et al. (2009) provide a comprehensive review of the durable goods literature. Among the most influential work, Coase (1972) raise the issue of time inconsistency in that a monopolist firm has both the incentive to maintain high price and the incentive to overproduce causing the price to fall, and conjecture that leasing might solve the dilemma (the well-known Coase conjecture). Bulow (1982) and Stokey (1981) formally confirm that, by leasing the product, the firm can avoid the time inconsistency problem. Later works outline scenarios under which Coase conjecture does not hold (Bond and Samuelson 1987). Desai and Purohit (1998) conclude that concurrent selling and leasing may be more profitable than pure leasing or pure selling. Their work has been extended into competition (Desai and Purohit 1999). Chien and Chu (2008) compare sale and leasing options when a monopoly of durable goods faces network effects. The literature also investigates the evolving nature of durable goods. For example, Dhebar (1994) studies a monopolist that supplies improved durable goods to a heterogeneous population. Levinthal and Purohit (1989) and Waldman (2003) address the issue that improving quality may encourage consumers to wait and hence makes time inconsistency problem worse. Jing (2011) analyzes the impact of social learning on dynamic pricing and consumer adoption of durable goods, and outlines conditions concerning consumers' different adoption times. It is also noted that durables are often accompanied by consumables or complementary products (for example, printers with cartridge), which may impact leasing and selling choices in a significant way (Gilbert and Jonnalagedda 2011, Bhaskaran and Gilbert 2005). Xiong et al. (2012) investigate the relationship between product durability and the firm's choice of leasing and selling in a dual channel supply chain. Agrawal et al. (2012) use an approach of life-cycle environmental impact and examine the relative profitability and environmental impact of selling and leasing. One stream of literature on durable goods focuses on secondary markets for used products. Yin et al. (2010) study the impact of multiple used goods markets on product upgrade and pricing. Huang et al. (2001) further expand the study of leasing to incorporate more realistic settings, such as indefinite time horizon, transaction cost and active secondary market for used goods. Hendel and Lizzeri (1999) propose a framework to analyze how a monopolist can interfere with secondary market. Esteban and Shum (2013) study the interaction between durability of the products and the secondary market characteristics. Tilson et al. (2009) study the best channel strategy when the durable good is marketed to both corporate and individual consumers.

Since the used products are lower-quality products compared with new products, our work also has thematic parallels to the literature on vertical differentiation, which refers to the differentiation of product performance quality in a market space where consumers are ranked according to their willingness to pay

(WTP) for quality (Moorthy 1984, Tirole 1988, Moorthy 1988). Vertical differentiation models are used extensively in the product line design literature (Moorthy and Png 1992) and have extended into product component commonality or product platform (Krishnan and Gupta 2001, Kim and Chhajed 2000, Desai et al. 2001) and software packages (Raghunathan 2000). Amaldoss and Shin (2011) investigate how the size of a low-end market influences a firm's profit and quality choice. Ishibashi and Matsushima (2009) state that competition from the low-end may benefit the high-end because the existence of low-end firms functions as a credible threat, which induces the high-end firms not to overproduce because price-sensitive consumers buy products from them. The vertical differentiation literature has been extended to remanufacturing, where the remanufactured products are normally modelled as lower quality products compared with new products (Atasu et al. 2008, Debo et al. 2005, Oraopoulos et al. 2012, Ferrer and Swaminathan 2010).

We complement existing literature on durable goods by changing the mechanism of cannibalization with a new structure of market space and investigate the impact of an additional international market space interacting with home market. In order to gain maximum insights for our research questions, we move away from the traditional focus of durable goods literature on comparing selling and leasing.

3 Model Formulation

In this paper, we build a model of vertical differentiation over an indefinite time horizon. This type of model has been used extensively in the literature on durable goods (Dhebar 1994, Agrawal et al. 2012). A monopolist firm operates over an indefinite number of discrete periods, consumers make their decisions based on their utility in each period, and any product launched in any period will last for two periods.

Firm and Product:

A monopolist firm introduces a durable good over an indefinite number of discrete periods. The durable itself lasts for two periods; we call it a car for convenience. A car newly introduced has a quality $\lambda = 1$, the next period it becomes a used car with quality $\lambda = 1 - D$, in which quality λ is a parameter and not a decision variable and D is the depreciation rate ($D < 1$). The unit cost of the product is a constant δ . In each period, the firm introduces a certain quantity of *new* cars and deals with the *used* cars that were introduced in the previous period. Therefore, they are only two types of products on the market in each period.

In this model, departing from the literature of durable goods, we assume that the firm only leases products and does not engaging in selling. We make this assumption for several reasons. First of all, it is no longer necessarily true that leased cars will be returned to the firm and sold cars will not be. In most European markets, such as France, a leasing contract carries the option to buy, and consumers who bought cars are encouraged to give back their cars in exchange for new cars (at additional cost). Therefore, there is little difference between leasing and buying in terms of ease to return cars. Second, in the durable goods literature, buying and selling would make a difference only if buying and selling lead to a different depreciation rate (Desai and Purohit 1998). In practice, the concept that "using it as if it is hired" will lead to higher depreciation rate if leased is outdated. In Europe, there are now very specific conditions under which a car can be returned. In France, when one of the authors returned leased cars to Citroen on several occasions, the conditions of the cars are thoroughly examined and even a tiny Cola spill on the seat is billed to the client. We can hardly imagine that in such an environment clients will be using a car less carefully only because it is leased. In our model, when leasing and buying carries the same depreciation rate, it will collapse into a purely leasing model. The focus of our paper is to study the stimulating effect of international market. A model with concurrent leasing and selling will not change the insights provided in this paper and, by unnecessarily complicating the analysis, lead to fewer results.

Market structure and Consumer Strategy

The market space consists of a home market and an international secondary market, both of which are vertically differentiated. Quality evaluation of the home market θ is uniformly distributed in $[0, 1]$, and that of the international secondary market $[0, V]$, where $V < 1$ to signify a less-wealthy market. It costs μ to ship one unit of used goods from the home market to the secondary market. In each period, consumers on both markets make their purchase decision based on their per-period utility derived from leasing cars, old or new, available on the market. The per-period utility is defined as $U = \theta \cdot \lambda - p$ when a consumer with quality evaluation θ uses a car with quality λ for *one period* and pays an associated rental price p . This utility function has the same form as the utility function of buying a product, except that the utility is obtained for using the product for one period. This per-period utility has been widely used in leasing literature (Agrawal et al. 2012, Desai and Purohit 1998). In each period, consumers decide whether to lease a new or used or not to lease based on the per-period utility.

Firm Strategy and Profit Function

In each period indexed as t , the OEM introduces q_t units of new cars to the home market and charges a price of p_t for leasing it for current period; from the q_{t-1} units of cars introduced in the previous period, it exports

f_t to the international market for a price of s_t and leases the rest $q_{t-1} - f_t$ on domestic market for a price of r_t .

The profit function for period t can be written as:

$$\Pi = (p_t - \delta) \cdot q_t + r_t \cdot (q_{t-1} - f_t) + (s_t - \mu) f_t$$

The parameters and decision variables are summarized in Table 1 and Table 2.

Resulting segmentation

On the domestic market, we label θ_{1t} as the consumer who is indifferent between new car and used car.

Consumers with quality evaluation above θ_{1t} will lease a new car. This relation can be described as follows:

$$\theta_{1t} : \theta_{1t} = 1 - q_t, 1 \cdot \theta_{1t} - p_t = (1 - D) \cdot \theta_{1t} - r_t. \theta_{2t} \text{ is the consumer who is indifferent between used car}$$

and non-consumption. Consumers with quality evaluation above θ_{2t} and below θ_{1t} will lease a used car.

This relation can be described as follows: $\theta_{2t} : \theta_{2t} = 1 - q_t - (q_{t-1} - f_t), \theta_{2t} \cdot (1 - D) - r_t = 0.$

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This relation can be described as follows: $\theta_{2t} : \theta_{2t} = 1 - q_t - (q_{t-1} - f_t), \theta_{2t} \cdot (1 - D) - r_t = 0.$

On the international market, θ_{3t} is the consumer who is indifferent between used car and non-consumption. Consumers with quality evaluation above θ_{3t} will lease a used car. The relation can be described as follows:
 $\theta_{3t} \cdot (1 - D) - s_t = 0$, $\theta_{3t} = V - f_t$

We use these equations which describes market segmentations:

$$\theta_{1t}: \theta_{1t} = 1 - q_t, 1 \cdot \theta_{1t} - p_t = (1 - D) \cdot \theta_{1t} - r_t.$$

$$\theta_{2t}: \theta_{2t} = 1 - q_t - (q_{t-1} - f_t), \theta_{2t} \cdot (1 - D) - r_t = 0.$$

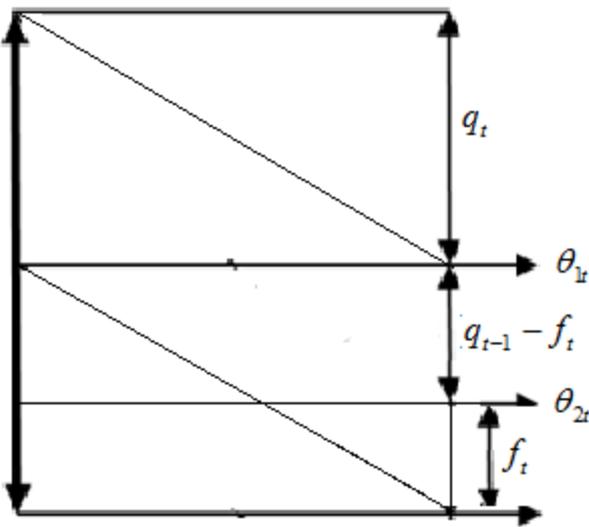
$$\theta_{3t} \cdot (1 - D) - s_t = 0, \theta_{3t} = V - f_t$$

We obtain prices as a function of quantities:

$$p_t = D(1 - q_t) + r_t$$

$$r_t = (1 - D)(1 - q_t) - (1 - D)(q_{t-1} - f_t)$$

$$s_t = (1 - D)(V - f_t)$$



Graph 1: Consumers Segmentation and Decision Time Frame in Stable Equilibrium

q_t : quantity of new products
f_t : quantity of used products
p_t : lease price of new product
r_t : lease price of used product
s_t : export price of used products at international market

Table 1: Decision variables

θ : quality evaluation
λ : quality of products
D : depreciation rate of products
δ : production cost
μ : transportation cost
V : market wealth of international market

Table

2: Parameters

4 Analysis for monopoly

In this section, we analyze the case in which a monopoly firm exports directly into a foreign market. Consistent with existing literature on durable goods over an indefinite time horizon, we focus our attention of steady state equilibrium where quantities of each period do not vary from period to period.

The profit function of the monopoly firm for period t can be written as:

$$\Pi = (p_t - \delta) \cdot q_t + r_t \cdot (q_{t-1} - f_t) + (s_t - \mu) f_t$$

Subject to:

$$p_t = D(1 - q_t) + r_t$$

$$r_t = (1 - D)(1 - q_t) - (1 - D)(q_{t-1} - f_t)$$

$$s_t = (1 - D)(V - f_t)$$

In steady state equilibrium, quantities do not change over time. We take out the notation t in quantity decision variables since they do not change.

Lemma 1: The optimal price and quality are as follows:

$$q = \frac{1 - \mu - \delta + V \cdot (1 - D)}{2(2 - D)}$$

$$f = \frac{(1 - D) \cdot (4V - 3DV + D - 2\delta) - \mu(4 - 3D)}{4 \cdot (2 - 3D + D^2)}$$

$$p = \frac{2(2 + \delta) - D \cdot (1 - \mu + V) - D^2(1 - V)}{4(2 - D)}$$

$$r = \frac{2(2 + \delta) - D \cdot (7 + \mu + 2\delta - V) + D^2(3 - V)}{4(2 - D)}$$

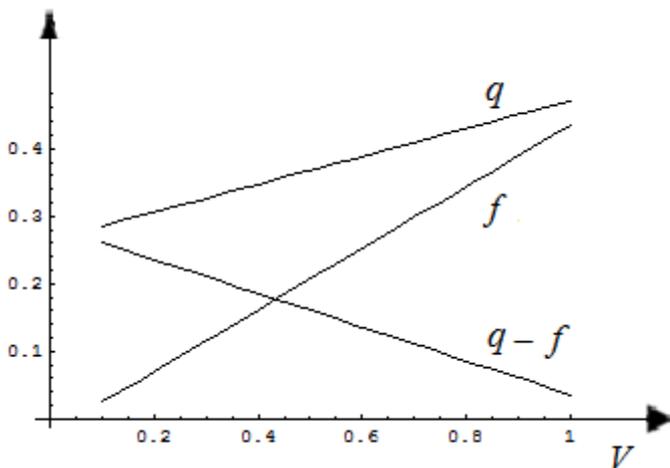
$$s = \frac{\mu(4 - 3D) - (1 - D) \cdot (D - 2\delta - 4V + DV)}{4(2 - D)}$$

Proofs of all Lemma and Propositions are provided in the appendix.

First of all, the fundamental question is how the presence of an international market for used cars would impact the OEM's decision in terms of quantity, price and market coverage. In our model, the international market is characterized by the market wealth V , which represents its willingness to pay for used cars.

Proposition 1: The impact of V can be described as follows:

$$\frac{\partial q}{\partial V} > 0, \quad \frac{\partial f}{\partial V} > 0, \quad \frac{\partial q - f}{\partial V} < 0, \quad \frac{\partial p}{\partial V} > 0, \quad \frac{\partial r}{\partial V} > 0, \quad \frac{\partial s}{\partial V} > 0$$



Graph 2: Stimulating Effect of the International Market. (All graphs are plotted in Mathematica).

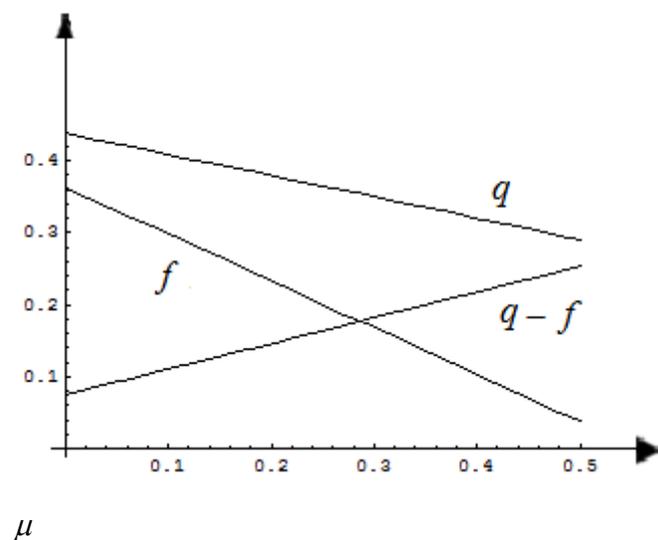
This proposition illustrates the basic stimulating effect of the market: when V increases, both the export of used cars and production of new cars increase, and the quantity of used cars remaining on the home market decreases. As can be expected, a wealthier foreign market increases export of used cars from the home market. The quantity of new cars increases for two reasons. First, because new cars are the sources of used cars, an increase in demand for used cars will lead new car quantity to increase. Second, used cars and new cars are substitutes; as more used cars are taken out of the market and the used cars quantity decreases, more new cars will be needed to take their place. Note that the export of used cars increases faster than production of new cars so used products at home decreases and reaches zero at one point. In addition, the price of used cars domestically increases, and market coverage decreases. This also results in a younger fleet as new car number increases and used car number decreases. The consumers overseas are not necessarily wealthier than those at home market. However, serving them has no cannibalization concerns. Therefore, they are served with priority when it comes to used cars. In fact, the export price is less than the domestic price and essentially the firm is exporting at a loss (we can obtain from Lemma 1 that

$s - r = \frac{1}{2} \cdot (-1 + V)(1 - D) - \frac{1}{2} \mu < 0$). According to our analysis, a profit maximizing monopolist should use the international market more as a stimulus tool to export more units and less as a profit generator because the reduced cannibalization at home allows for higher profit from new products.

An equally important component of the system is the link between the home market and the international market. The transportation cost μ illustrates the barrier for used cars to enter the international market. This barrier can be geographical distance to transport it, or tariff to be paid, or conversion cost to get the used car suitable for international market (for example, from left-hand to right-hand steering).

Proposition 2: The impact of μ can be described as follows:

$$\frac{\partial q}{\partial \mu} < 0, \quad \frac{\partial f}{\partial \mu} < 0, \quad \frac{\partial (q - f)}{\partial \mu} > 0, \quad \frac{\partial p}{\partial \mu} > 0, \quad \frac{\partial r}{\partial \mu} > 0, \quad \frac{\partial s}{\partial \mu} > 0$$



Graph 3: Effect of the Transportation Cost

An increasing μ represents a poorer connection between home market and international market. Unsurprisingly, the export of used cars decreases, which leads to a decrease in the production of new cars. In Russian Far East, a higher tariff has led to a dramatic increase in price and decrease in quantity, which triggered even social unrest (Financial Times December 21, 2008). A decreasing μ represents a better connection between two markets and stimulates both used car export and new car production.

Apart from market characteristics, such as V and μ , the product characteristic is also an important component in the system. The quality of the used product interacts with market characteristics to impact the whole mechanism. For simplicity of exposition, we use a single variable $d = 1 - D$ to denote the quality of the used cars, where D is the depreciation rate.

Proposition 3: The impact of used car quality can be described as follows: $\frac{\partial^2 f}{\partial d \partial V} > 0$

$\frac{\partial^2 f}{\partial d \partial V} > 0$ states that the high quality of used cars reinforces the stimulating effect of wealthier international market. That is, export of used cars with higher quality rises faster when the market wealth increases than that of lower quality. In other words, used cars with higher quality, such as used Japanese cars with low mileage, benefit more from international trade. Recall that $d = 1 - D$ and

$s - r = \frac{1}{2} \cdot (-1 + V)(1 - D) - \frac{1}{2} \mu < 0$. We can obtain $\frac{\partial(s - r)}{\partial d} < 0$, which states that a higher quality of used cars increases the prices difference of used products at home and abroad. As product quality goes up, cannibalization pressure also goes up. Therefore, the firm is more willing to export at a loss.

Apart from market force, the export of used cars is very much influenced by legislation on the home market. For example, in Japan drivers are required by law to submit three-year-old cars to strict road tests costing at least \$1250 – with subsequent tests every two years. It is equally expensive to dispose of them too. This makes aging cars worth very little, and owners normally relinquish ownership before it gets too expensive. This stringent control for used cars in Japan is effectively pushing them out of Japan. What is the impact of such legislation on the system? We define w as the penalty when leasing used cars at home market.

Proposition 4: The impact of w can be described as follows: $\frac{\partial f}{\partial w} > 0, \frac{\partial q}{\partial w} = 0$

The traditional wisdom is that taking out used cars will allow for more new cars. It may seem logical that imposing a penalty on used cars would motivate consumers to dispose them and then get a new one, thus stimulating new car production. However, examining the details of the operation reveals a more subtle mechanism. It is true that penalizing ownership of used cars pushes them out of the home market. However, at the same time, it also reduces the number of consumers in the home market that would lease used cars. In other words, some consumers who would lease a used car, now due to the new penalty, refrain from leasing at all. Therefore, this type of stimulus is not effective to stimulate new car production and should be used carefully or, at least with the right expectations.

5 The Effect of Third Party Collectors

Shipping used cars from Germany to Hungary is only several hours of drive, but such a trip by ship from Japan to Africa could take months. It is not always the best idea for OEMs to export directly to international markets for various reasons. In such scenarios, normally it is those agents specializing in cross-border trade of used cars that would collect used cars, through auctions or other mechanisms, and then export them to international markets. Since these agents make quantity and price decisions to maximize their own profit, this causes an interesting interaction with the OEMs and alters the mechanism of the system. One interesting issue is the power structure between the OEM and the agent. If the price is fixed through auctions, which is the case in Japan, it is market force that decides. However, the price may also be set by the large OEMs.

In this section, we analyze the case in which a monopoly firm exports to the international market through an agent. Again, we focus our attention on steady state equilibrium where quantities do not vary from period to period.

When the agent is a price taker, the profit function of the monopoly firm for period t can be written as:

$$\Pi = (p'_t - \delta) \cdot q'_t + r'_t \cdot (q'_{t-1} - f'_t) + s'_t f'_t$$

Subject to:

$$p'_t = D(1 - q'_t) + r'_t$$

$$r'_t = (1 - D)(1 - q'_t) - (1 - D)(q'_{t-1} - f'_t)$$

$$f'_t = \frac{(1 - D)V - \mu - s'_t}{2(1 - D)}$$

The first two constraints are same as in direct case. The final constraint $f'_t = \frac{(1 - D)V - c - s'_t}{2(1 - D)}$ illustrates

relationship between export quantity and export price when using an agent. When OEM sets export price, the agent chooses price to maximize her own profit. $\pi_a = (p_a - s'_t - \mu) \cdot (V - \frac{p_a}{1 - D})$. Therefore the optimal

agent price is $p_a = \frac{(1 - D)V + \mu + s'_t}{2}$. The export quantity is $f'_t = V - \frac{p_a}{1 - D} = \frac{(1 - D)V - \mu - s'_t}{2(1 - D)}$. In steady

state equilibrium, quantities do not change over time. We take out the notation t in quantity decision variables since they do not change over time.

Lemma 2: When agent is a price taker, the optimal quantities of the OME are as follows:

$$q' = \frac{-4 + 2\mu + D + 3\delta - 2V + 2DV}{2(8 - 5D)}$$

$$f' = \frac{(1 - D) \cdot (4V - 3DV + D - 2\delta) - c(4 - 3D)}{2(1 - D)(8 - 5D)}$$

When the agent and OEM have equal power, the profit function of the monopoly firm for period t can be written as: $\Pi = (p_t^* - \delta) \cdot q_t^* + r_t^* \cdot (q_{t-1}^* - f_t^*) + s_t^* f_t^*$

Subject to:

$$p_t^* = D(1 - q_t^*) + r_t^*$$

$$r_t^* = (1 - D)(1 - q_t^*) - (1 - D)(q_{t-1}^* - f_t^*)$$

The export price is set when demand equals supply of used cars on the international market. In steady state equilibrium, quantities and price do not change over time. We take out the notation t in price and quantity decision variables since they do not change over time.

Lemma 3: The optimal quantities of the OME are as follows:

$$q^* = \frac{1 - \mu - \delta + V - DV}{2(2 - D)}, \quad f^* = \frac{(1 - D) \cdot (4V - 3DV + D - 2\delta) - \mu(4 - 3D)}{4(1 - D)(2 - D)}$$

In the previous section, we showed that an increased willingness to pay on the international market stimulates the export of used cars and also the production of new cars. How would the stimulating effect change in face of channel structure?

Proposition 5 .

$$0 < \frac{\partial q'}{\partial V} < \frac{\partial q^*}{\partial V} = \frac{\partial q}{\partial V}, \quad 0 < \frac{\partial f'}{\partial V} < \frac{\partial f^*}{\partial V} = \frac{\partial f}{\partial V}$$

According to this proposition, the derivatives of both export and new car production with respect to V with agent as the price taker are less than those in the direct case. That is, the channel structure makes market stimulus of V less effective. Yet, the derivative when export price is set by market force is greater than derivative when OEM sets the price. That is, a more balanced power structure mitigates the negative impact of channel structure.

In the previous section, we showed that a better connection between home market and international market stimulates export of used cars and production of new cars. How would the stimulating effect change in face of channel structure?

Proposition 6.

$$\frac{\partial q^*}{\partial c} < \frac{\partial q'}{\partial c} < \frac{\partial q}{\partial c} < 0, \quad \frac{\partial f^*}{\partial c} < \frac{\partial f'}{\partial c} < \frac{\partial f}{\partial c} < 0$$

According to this proposition, the derivatives of both export and new car production with respect to μ are less than those in the direct case. That is, the agent structure causes the firm to be more sensitive to transportation change: both export of used cars and new car production decrease at a magnitude greater than in direct case. A more balanced power structure causes the quantity to be more sensitive to transportation

cost increase. This is consistent with the case of Japan in which the agent and OEM determines price with market force and the export quantity is very sensitive to change in tariff. Comparing Proposition 5 and 6, we can see that impact of V and μ behave differently in the channel structure. With V , the channel structure makes the whole system less sensitive to parameter change, or, in other words, absorbs part of the shock to the system. With μ , the channel structure makes the system more sensitive to parameter change, or amplifies the impact of parameter change.

In the previous section, we showed that imposing a penalty on used cars pushes more cars out of the home market but does not have the intended effect of stimulating new car production. How would the effect of penalty change in face of channel structure?

Proposition 7 .

$$\frac{\partial q'}{\partial w} < \frac{\partial q^*}{\partial w} = \frac{\partial q}{\partial w} = 0, \quad 0 < \frac{\partial f'}{\partial w} < \frac{\partial f^*}{\partial w} = \frac{\partial f}{\partial w}$$

According to this proposition, the channel structure with agent as price taker reduces the effectiveness of penalty of stimulating export and causes it to backfire more. That is, for the same amount of penalty, the export increase with agent as a price taker is less than that of direct case, but new car production decrease is greater than that direct case. When export price is set by market force, the effect of penalty is the same as direct case.

6 Conclusions and Further Research

The cross-border trade of used cars has been on the rise as the trend of globalization continues. If managed properly, the cross-border export of used cars can be a very effective tool to improve operations. In durable goods industries, managing the cannibalization between new products and used products is always a challenging issue. Some companies go as far as destroying used products to avoid cannibalization, causing huge losses to the company and to society. Exporting used products to a physically separate market makes cannibalization much less of a concern. In addition, since new products provide a source for used products, the additional demand from foreign markets for used products provides a new stimulus for new product production. However, with multiple parties involved in the cross-border trade, such as the governments on both sides of the border, or import/export agents as the middlemen, a firm needs to carefully manage the operation in order to exploit the advantage of the international market. In this paper, we build on existing literature and construct a model of two interconnected vertically differentiated markets to examine how the presence of an international market may impact management practices concerning durable goods. Our main results are as follows:

1. A higher willingness to pay on the international market stimulates production of new products.
2. A better connection between international market and home market stimulates domestic production of new products.
3. High quality of used products reinforces the stimulating effect of the international market.
4. Imposing a penalty on used products indeed pushes them out of the market and stimulates export, but such a measure does not have the intended consequence of stimulating production of new products.
5. If the OEM relies on agents to export used cars, this causes the system to behave differently. The stimulating effect of the international market is very much reduced. Export quantity is more vulnerable to tariff change than in direct case. The government stimulus also becomes less effective.

Our paper has several limitations, which we wish to overcome in future research. First, we assume that product quality is given and not a decision variable. In practice, the firm may well adjust its quality or even technology choice when there is an international market available for export. Second, we assume that the OEM is a monopoly and there is no strategic reaction from competitors. In practice, strategic competition, either at home or abroad, plays an important role in the choice of export and production.

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Appendix 1: Proof of Lemma 1

From the constraints, we obtain:

$$p_t = D(1 - q_t) + r_t, \quad r_t = (1 - D)(1 - q_t) - (1 - D)(q_{t-1} - f_t), \quad s_t = (1 - D)(V - f_t)$$

Substituting them into the profit function $\Pi = (p_t - o) \cdot q_t + r_t \cdot (q_{t-1} - f_t) + (s_t - c)f_t$, we obtain a function of quantities:

$$2(-1 + D)f_t^2 - q_t^2 + (1 - D)(1 - q_{t-1})q_{t-1} - q_t(-1 + o + 2q_{t-1} - 2Dq_{t-1}) + f_t(-c + (1 - D)(-1 + 2q_t + 2q_{t-1} + V))$$

Since we are only interested in stable equilibrium $q_{t-1} = q_t$, the profit function becomes

$$2(-1 + D)f_t^2 + q_t(2 - D - o - 4q_t + 3Dq_t) + f_t(-c + (1 - D)(-1 + 4q_t + V))$$

Since all quantities and prices are obtained in stable equilibrium, we take out the notation t . We solve the first order conditions and obtain the only interior solution:

$$q = \frac{1 - \mu - \delta + V \cdot (1 - D)}{2(2 - D)}, \quad f = \frac{(1 - D) \cdot (4V - 3DV + D - 2\delta) - \mu(4 - 3D)}{4 \cdot (2 - 3D + D^2)}$$

We check the second order conditions:

$$\frac{\partial^2 \pi}{\partial q^2} = -8 + 6D, \quad \frac{\partial^2 \pi}{\partial f^2} = -4 + 4D, \quad \frac{\partial^2 \pi}{\partial q \partial f} = 4 - 4D$$

Therefore, the Hessian is semi-definitive and it is the optimal solution.

Substitute quantities back to price expressions, we obtain price expressions:

$$p = \frac{2(2 + \delta) - D \cdot (1 - \mu + V) - D^2(1 - V)}{4(2 - D)}$$

$$r = \frac{2(2 + \delta) - D \cdot (7 + \mu + 2\delta - V) + D^2(3 - V)}{4(2 - D)}$$

$$s = \frac{\mu(4 - 3D) - (1 - D) \cdot (D - 2\delta - 4V + DV)}{4(2 - D)}$$

Appendix 2: Proof of Proposition 1

Note that signs of the derivatives are obtained with $D < 1$ in all proofs.

The derivatives of quantities (obtained in Lemma 1) with respect V can be seen as follows:

$$\frac{\partial q}{\partial V} = \frac{1 - D}{4 - 2D} > 0, \quad \frac{\partial f}{\partial V} = \frac{4 - 3D}{8 - D} > 0, \quad \frac{\partial q - f}{\partial V} = -\frac{1}{4} < 0$$

The derivatives of prices (obtained in Lemma 1) with respect V can be seen as follows:

$$\frac{\partial p}{\partial V} = \frac{-D + D^2}{4(2 - D)} > 0, \quad \frac{\partial r}{\partial V} = \frac{D - D^2}{4(2 - D)} > 0, \quad \frac{\partial s}{\partial V} = \frac{-(1 - D) \cdot (-4 + D)}{4(2 - D)} > 0$$

Appendix 3: Proof of Proposition 2

The derivatives of quantities with respect to μ can be seen as follows:

$$\frac{\partial q}{\partial \mu} = \frac{1}{-4 + 2D} < 0, \quad \frac{\partial f}{\partial \mu} = \frac{-4 + 3D}{4(2 - D)(1 - D)} < 0, \quad \frac{\partial q - f}{\partial \mu} = \frac{1}{4 - 4D} > 0$$

The derivatives of prices with respect to μ can be seen as follows:

$$\frac{\partial p}{\partial \mu} = \frac{D}{4(2 - D)} > 0, \quad \frac{\partial r}{\partial \mu} = \frac{D}{4(2 - D)} > 0, \quad \frac{\partial s}{\partial \mu} = \frac{4 - 3D}{4(2 - D)} > 0$$

Appendix 4: Proof of Proposition 3

The expressions of derivatives with respect to V is given by $\frac{\partial q}{\partial V} = \frac{1-D}{4-2D}$, $\frac{\partial f}{\partial V} = \frac{4-3D}{8-D}$

Substituting $d = 1 - D$ and take derivatives with respect to d , we obtain $\frac{\partial^2 f}{\partial d \partial V} > 0$

Appendix 5: Proof of Proposition 4

When a penalty is imposed, the consumer at home market will pay $r_t + w$ to lease a used product. To obtain the optimal solution when penalty is present, the process remains the same as in Lemma 1 except r_t is replaced by $r_t + w$ in the price expression

$$p_t = D(1 - q_t) + r_t + w$$

$$r_t + w = (1 - D)(1 - q_t) - (1 - D)(q_{t-1} - f_t)$$

$$s_t = (1 - D)(V - f_t)$$

We obtain the only interior solution

$$q_t = \frac{1 - \mu - \delta + V \cdot (1 - D)}{2(2 - D)}$$

$$f_t = \frac{-2\delta + 4V + D^2(-1 + 3V) + D(1 + 2\delta - 7V - w) + 2w - \mu(4 - 3D)}{4 \cdot (2 - 3D + D^2)}$$

We check the second order condition, and the Hessian is semi definitive and it is the optimal solution. We take first order derivative with respect to penalty, and obtain the results

$$\frac{\partial f}{\partial w} > 0, \quad \frac{\partial q}{\partial w} = 0$$

Appendix 6: Proof of Lemma 2

The proof follows identical steps as in Lemma 1. We solve the price equations and put the price expressions into profit function and then quantities constant for all periods.

The profit function becomes:

$$q'(2-D-\delta-4q'+3Dq')+f'((1-D)(4q'+V-1)-\mu)+3(D-1)f'^2$$

We obtain only interior solution:

$$q' = \frac{-4+2\mu+D+3\delta-2V+2DV}{2(8-5D)}, f' = \frac{(1-D)\cdot(4V-3DV+D-2\delta)-\mu(4-3D)}{2(1-D)(8-5D)}$$

$$\text{We check the second order condition: } \frac{\partial^2 \pi}{\partial q'^2} = -8+6D, \frac{\partial^2 \pi}{\partial f'^2} = -6+6D, \frac{\partial^2 \pi}{\partial q' \partial f'} = 4-4D$$

Therefore, the Hessian is semi-definitive and it is the optimal solution.

Appendix 7: Proof of Lemma 3

As in Lemma 1 and 2, we solve the price equations and put the price expressions into profit function and set quantity constant across periods, The profit function becomes:

$$q^*(2-D-\delta-4q^*+3Dq^*)+f^*(-1+D+4q^*-4Dq^*+s)+(D-1)f^{*2}$$

We obtain only one interior solution as a function of export price

$$q^* = \frac{D+2s-\delta}{2D}, f^* = \frac{D-D^2-2\delta+2\delta D+4s-3Ds}{2(1-D)D}$$

Since the Hessian is semi-definitive, therefore it is the only optimum.

The export quantity above is the quantity that the firm is willing to supply for a given export price. The demand for the export quantity based on export price in the agent case is given by

$$f^* = \frac{(1-D)V-\mu-s}{2(1-D)}$$

We set demand equal supply, and the equilibrium price is given by

$$s = \frac{2\delta+D(V-1-\mu-2\delta)+D^2(1-V)}{2(2-D)}$$

Substituting the equilibrium price back, we obtain

$$q^* = \frac{1-\mu-\delta+V-DV}{2(2-D)}, f^* = \frac{(1-D)\cdot(4V-3DV+D-2\delta)-\mu(4-3D)}{4(1-D)(2-D)}$$

Appendix 8: Proof of Proposition 5

From the calculation in Lemma 1, 2, 3, we calculated the derivative with respect to V, simple algebra reveals

that $0 < \frac{\partial q'}{\partial V} < \frac{\partial q^*}{\partial V} = \frac{\partial q}{\partial V}$, $0 < \frac{\partial f'}{\partial V} < \frac{\partial f^*}{\partial V} = \frac{\partial f}{\partial V}$

Appendix 9: Proof of Proposition 6

From the calculation in Lemma 1, 2, 3, we calculated the derivative with respect to μ , simple algebra

reveals that $\frac{\partial q^*}{\partial \mu} < \frac{\partial q'}{\partial \mu} < \frac{\partial q}{\partial \mu} < 0$, $\frac{\partial f^*}{\partial \mu} < \frac{\partial f'}{\partial \mu} < \frac{\partial f}{\partial \mu} < 0$

Appendix 10: Proof of Proposition 7

When a penalty is imposed, the consumer at home market will pay $r_t + w$ to lease a used product. To obtain the optimal solution when penalty is present, the process remains the same as in Lemma 2 and 3, except r_t is replaced by $r_t + w$ in the price expression. We obtain the only interior solution. We check the second order condition, and the Hessian is semi-definitive and it is the optimal solution. We take first order derivative with

respect to penalty, and obtain the results $\frac{\partial q'}{\partial w} < \frac{\partial q^*}{\partial w} = \frac{\partial q}{\partial w} = 0$, $0 < \frac{\partial f'}{\partial w} < \frac{\partial f^*}{\partial w} = \frac{\partial f}{\partial w}$