Second-Hand Markets and Collusion by Manufacturers of Semidurable Goods*

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Abstract

The focus of the present work is to study the impact of the second-hand market the collusive behavior. I analyze firms' preferences for having an active second-hand market and whether policies (i.e. leasing policy, buy-back policy and warranty policy) that affect the functioning of the second-hand market strengthen collusion. I show how collective incentives to adopt strategies that strengthen collusion often differ from monopoly incentives to achieve higher profits.

Keywords: Bertrand competition, buy-back policies, collusion, leasing, semi-durability, second-hand market, warranty.

JEL classification: D21, D43, L11, L13, L25.

1 Introduction

The focus of the present work is to study the implications of the second-hand market the collusive behavior.[1] Whereas most of the previous literature focuses on the implications of the second-hand market on a monopolist's profitability, I analyze firms' preferences for having an active second-hand market and whether policies (i.e. leasing policy, buy-back policy and warranty policy) that affect the functioning of the second-hand market strengthen collusion. Collective incentives to adopt these policies may not necessarily coincide with individual incentives to achieve a higher profit. It follows that manufacturers of durable goods may increase the scope of the secondary market, even though a monopolist may have the opposite incentive.

A large strand of the industrial organization literature analyzes the durable-goods market in the presence of a monopolist. Once the quality (or the durability) of goods deteriorates, the existence of the second-hand market is endogenously explained by introducing consumer heterogeneity in the valuation of quality. As units age and quality decreases, goods are traded from high-valuation to low-valuation consumers on competitive secondary markets, allowing owners to update to their preferred quality. Different authors (Waldman, 1996a, 1997; Hendel and Lizzeri, 1999a; Anderson, S. and V. Ginsburgh 1994) have shown that in this context the monopolist may increase monopoly profit with the presence of a secondary market because he can better allocate the good amongst consumers and take advantage of an indirect form of price discrimination. However, the potential substitutability of different vintages means the availability of used units lowers the monopolist's new unit price. One possible response is for the monopolist to reduce the durability of new units. This reduces the substitutability of new and used units and allows the firm to increase the price for new units. Another possibility is for the firm to reduce, or even eliminate, the availability of used units where the return is again a higher new unit price. A real-world practice along these lines is the lease-only policy (Johnson and Waldman, 2003, Hendel and Lizzeri, 1999a);[2] that is, the policy of leasing but refusing to sell output. However, there are in fact many examples in which manufacturers seem to intervene in the opposite direction and encourage an active second-hand market. For example, many manufacturers allow transfers of warranty coverage between owners. Also, car manufacturers encourage dealers to accept trade-ins and pursue policies that seem designed to facilitate transactions in the used market. Infinity and Lexus extend warranty coverage to used cars. IBM, Dell and other computer manufacturers sell

[1] Bresnahan (1987) and Sudhir, analyzing the American automobile industry, observe a predominant collusive behavior among car manufacturers in the sale of their goods.

[2] When the monopolist offers a lease-only policy he actually sells the service flow of the (new or used) goods for the length of the contract period. In such a situation there is practically no second-hand market because no new durable goods are sold on the primary market.

refurbished equipment and provide warranties for used goods.

One aspect that is missing from the previous literature is the presence of multiple firms competing in such markets. The incentives to interfere with or eliminate an active second market will be different if we consider monopoly incentives or oligopoly incentives. Collective incentives to sustain collusion over time and monopoly incentives to achieve higher profit do not necessarily move in the same direction. In spite of the fact that a monopolist manufacturer has an incentive to eliminate the availability of used units, sometimes manufacturers operate in the opposite direction.

With durable goods and no second-hand market, Ausbel and Deneckere (1987) and Gul (1987) show that intertemporal substitutability in demand facilitates collusion via rational expectations on the part of consumers. The possibility of intertemporally substituting consumption (i.e. decide when to buy durable goods based on the expected price for new goods in the future) constrains the maximum price that a defector can charge in the defection period, hence it reduces the benefit that the defector can gain by deviating. Consumers will forgo the utility of buying a new good today if they expect its price to be substantially lower tomorrow.

The second-hand market introduces a different channel through which the gain from defection is reduced. The presence of a second-hand market affects demand for new goods in two ways: the buyers of new goods can sell them when they become used and the resale value positively influences the demand for new goods (resale effect); on the other hand, used goods constitute a cheap (imperfect) substitute for new goods and this depresses the demand for new goods (substitution effect). The first aspect introduces dynamic considerations into consumer demand: the producer takes into account that the quantity sold in the current period has an indirect, as well as a direct, effect on current profits. A higher level of current production lowers tomorrow's secondary market price (the current production of new goods adds to supply on the future secondary market) and erodes consumers' willingness to pay for a new good today by reducing its resale value. Because the value of a new good today depends on its expected price on tomorrow's secondary market, a firm's current profits also depend on its own future production, which can influence the secondary-market price. In this context, if firms maintain a collusive price under the threat of a price war, then consumers may foresee price wars in the wake of defection and possibly lower their willingness to pay for new goods. The menace of a price war may induce consumers to expect lower prices for used goods. The presence of cheap new goods after a defection will make used goods less desirable and drive down their equilibrium price. This affects consumers' willingness to pay for new goods and the punishment is felt even at the time of the defection. In this setting, punishments harsher even than grim trigger strategies are possible.[3] By threatening to price

[3]Similarly harsher strategies could also be used without the presence of a secondary market as they will

below marginal cost in the post-deviation period, competing firms can drive the expected future price of used goods to zero and reduce the profit from new goods in the defection period by completely removing the resale-value component of demand.

Durable goods in my model live for two periods and depreciate in the second period. There are two groups of consumers with different taste for quality. The second-hand market improves the efficiency of allocation of new and used products among heterogenous consumers. Therefore, firms sell new goods more frequently and may achieve higher profit even if the monopoly price is lower with the secondary market. With durable goods (with or without a secondary market), the extra incentive to sustain collusion is provided by the extra punishment inflicted on the defector in the defection period, which is absent in a non-durable environment. Hence, the firms' choice or whether to have a second-hand market or not depends on the size of the punishment inflicted in the defection period. In particular, the ability to enforce collusion depends on the possibility of consumers to intertemporally substitute consumption if there is no second-hand market, or on the equilibrium price of used goods if there is.

The model predicts that for collusive purposes having an active second-hand market is preferable every time the marginal cost of production is either high or low and there is a sharp reduction in the quality of the durable good over time. In general, the second-hand market will be preferred for collusive purposes whenever consumer utility from keeping the used good is low because it is costly to keep the good over time. More specifically, if the unitary profit from selling a good is low because of high marginal cost, the relative drop in price in the defection period is bigger in the presence of a secondary market, hence collusion is sustained under a broader range of parameters in this case. However, monopoly profit is likely to be lower with a second-hand market in such a situation. The ability to collude is also higher with the secondary market if the marginal cost and the quality of used goods are low. If the quality of the used good is low and there is no secondary market, consumers' incentives to intertemporally substitute consumption decrease, as does the leverage that firms can use to punish the defector in the defection period. Moreover, consumers with a used good (and with no possibility to resell it) are tempted to buy a new good and scrap the used one. If the marginal cost is also low, the defector has an incentive to further lower the price in the defection period to sell the good to all consumers (with and without the good) and maximize its profit. In such a situation, the punishment inflicted to the defector in the defection period is minimal, so the ability to collude compared with a second-hand market is decreased. In particular if the marginal cost is low enough, firms will prefer to sell new goods to all consumers every period by lowering the price of the good. Consumers always scrap a used good to buy a new good with consequent welfare loss. If this is the

affect the willingness of consumers to intertemporally substitute consumption.

case even with durable goods, there is no intertemporal link in demand and no further incentive to sustain collusion than in the standard Bertrand case. In contrast, with the presence of a secondary market, firms always achieve a higher profit because of the more efficient allocation and consequent increase in total welfare. Consumers never scrap the used good but rather they resell it to low-valuation consumers. Therefore, the demand for new units preserves the dynamic component and consequently the ability to enforce collusion is reinforced. More generally, the pre-eminence of the second-hand market both for collusion purposes and profitability arises every time the utility that consumers get from keeping the used good is low, either because the quality of the good is low or because it is costly to keep the good over time. I show that in those markets where

Finally, I consider an environment in which firms may implement different strategies aimed at interfering with the secondary market even if they cannot prevent a priori the possibility for consumers to resell their goods in a decentralized market. I argue that the ability to collude and the maximum achievable profit change as different policies are undertaken by firms in order to affect the secondary market. In particular, a policy aimed at eliminating the secondary market, such as a leasing policy, would eliminate the dynamic consideration in consumer decisions (with leasing contracts, the manufacturer is able to sell only the flow of service derived from products) and lessen the possibility of collusion: the absence of a second-hand market reduces the punishment that can be inflicted on a defector. In particular, leasing reduces the range of the discount factor over which collusion is sustainable, but it will always increase profit with respect to a selling-only policy. On the other hand, the range of the discount factor that makes collusion sustainable is enlarged under the buy-back policy and transferable warranties. These policies preserve the existence of a secondary market, increase the market value of used units and consequently the extra punishment inflicted on the defector in the defection period. However, both policies are costly to implement (unlike the leasing policy), and therefore they do not always generate a higher profit.

The paper is organized as follows: in Section 2, I develop the main mechanism that reinforces collusion through the secondary market. In Section 3, I study firms' incentives to eliminate the secondary market by comparing the previous results with Gul's (1987) and Ausubel Deneckere's (1987) results adapted in the present context. In Section 4, I study different policies aimed at influencing the second-hand market: specifically I look at leasing policy and buy-back policy and I analyze the incentive for manufacturers to offer warranty coverage for used goods. Section 5 concludes.

2 The Model

Consider an infinite-horizon discrete-time model with infinitely lived consumers, one durable good and one other good as numeraire. The quality of the durable good is $q \in \{\alpha, 1\}$; assume that it lasts for two periods only. The durable good is "new" during the period in which it is produced, "used" during the following period and worthless thereafter. Durability is associated with the quality of used goods. The quality of new units is normalized to 1 and the quality of used units is $\alpha \in (0, 1)$. Suppose there are G firms producing durable goods. The firms face no capacity constraints and produce durable goods at a constant marginal cost $c > 0$. All firms simultaneously set their price at the beginning of every period and are committed to selling to all interested consumers at that price during that period. Let $p_{g,t}^N$ be the price of new goods set by firm g in period t. The lowest price in a period is the market price in that period,

$$p_t^N = \min\{p_{1,t}^N, ..., p_{G,t}^N\} \tag{1}$$

and all consumers buy from firms charging that price.[4] If more than one firm sets a price equal to the market price, then sales are split equally between all such firms. All firms are risk-neutral and discount future profits by the same discount factor δ_f. Hence, each firm's profit in a market period is simply its sales multiplied by the difference between its price and its marginal cost. Let D_t^N be the demand for new goods in period t, the industry profit function in period t is $\Pi_t = \left(p_t^N - c\right) D_t^N$.

On the demand side there are two groups of consumers, denoted by h and l, with masses n_h and n_l. Each consumer wishes to buy at most one unit of the good in each period. Consumers differ as to their valuation of the good. Consumers in group h have a high willingness to pay θ_h and those in group l have a lower willingness to pay for each unit, i.e. $\theta_l < \theta_h$. Assume that $n_h < n_l$ in order to guarantee that the equilibrium price on the second-hand market (when it exists) is positive.

The consumption decision is a function of current prices, price history and the stock of used goods available in each period. Consumers form correct expectations concerning future prices and anticipate that by buying a new product in t they can collect its resale value in $t + 1$ as extra income whenever resale is feasible. Each consumer's current utility is quasi-linear in income $u_t = q\theta_i + y_t$ where y_t is the endowment of income in period t. The lifetime utility of a consumer is given by $U = \sum \delta^{t-1} u_t$, where δ is the discount factor common to all consumers.

To simplify the analysis, I focus on stationary equilibria in which new and used good prices are time invariant (see for example Dutta, Matros and Weibull, 2007, Hendel and

[4] I assume that firms cannot price discriminate among consumers.

Lizzeri, 1999a, 1999b, Johnson and Waldman, 2003). The values of all parameters are common knowledge.

In each period there are two markets: an imperfectly competitive market for new goods and a perfectly competitive market for used goods. The market for used goods allows high-valuation consumers to trade in their old units for new ones, and permits low-valuation consumers to purchase used units in every period. All consumers have access to both markets. There are no transaction costs in either market. Given the form of utility, consumers differ only in their preference for quality.

Equilibrium.

Firms know all past prices announced in all earlier periods (in particular, firms hold correct expectations along the induced price path and after unilateral deviations from this path), the stock of used goods available on the market at the beginning of each period, as well as the actions chosen by consumers in the past. This information defines the state of the game played by G firms. A pure behavior strategy for a firm is accordingly a function that specifies the price to be set in each period t, conditional upon the state in that period.

Firms' and consumers' strategies constitute a subgame perfect equilibrium if, in all periods and states, each firm maximizes its expected discounted future stream of profits and each consumer maximizes his own utility, given all other players' strategies. Notice that if the current state depends on the stock of goods available then the strategic interaction is not repeated.[5]

In general, any price between marginal cost and the monopoly price can be sustained as a subgame perfect equilibrium in grim trigger strategies. However, for simplicity and without loss of generality, I shall focus on the monopoly outcome. To focus attention on the most relevant cases, assume:

- *(a1)* the monopolist has no incentive to sell new goods to low-valuation type consumers (i.e. $((1-\alpha)\theta_h + \alpha(1+\delta)\theta_l - c)n_h > ((1+\alpha\delta)\theta_l - c)\frac{n_h+n_l}{2} > 0$)

- *(a2)* it could never be socially optimal to sell new units to all low-valuation types if any used units were available, i.e. $c > (1-\alpha)\theta_l$.

The presence of vertically differentiated goods (new and used goods), along with consumer heterogeneity, will create the opportunity for trade in a decentralized secondary market. Of course the possibility of getting positive utility from the presence of both new and used goods will constrain the monopolist in terms of the maximum price that he can charge on the primary market: The used good represents a cheaper alternative for the new product.

[5] See Dutta, Matros and Weibull, 2007 for further discussion.

Since the utility function is quasi-linear and there are no transaction costs, consumers separate their current decision from their future decisions and determine their optimal consumption by simply comparing the flow of utility that they derive from each possible choice.

Lemma 1 *Consumers' optimal consumption is determined by* $\max\{\theta_i - p_t^N + \delta p_{t+1}^U, \alpha\theta_i - p_t^U, 0\}$.

From the previous lemma, and given a stationary environment, consumers' choices will be the same at every date along the equilibrium path, i.e. high-valuation type consumers buy new units in every period and low-type consumers buy used units (for applications of the same framework see Anderson and Ginsburgh (1994), Esteban and Shum (2007), Hendel and Lizzeri (1999a, 1999b), and Waldman (1996a, 1997), among others). A generalization of the model, where frictions in the secondary market make consumers' replacement infrequent is analyzed in Hendel and Lizzeri (1999b), Schiraldi (2008) and Stolyarov (2002).[6]

The timing of the game is as follows. In each period, firms simultaneously announce the price for a new unit of output. A second-hand market opens up where prices equate supply and demand; consumers simultaneously decide whether or not to buy a new good and whether or not to buy or sell a used good on the second-hand market. In each period, the supply of used goods depends on the new goods produced in the previous period. The price on the second-hand market, p_t^U, is an endogenous variable determined by equating supply and demand.

Monopoly.

Proposition 1 *The price that maximizes the monopoly present discounted profit in a subgame perfect equilibrium is* $p^m = (1-\alpha)\,\theta_h + p^U + \delta p^U \ \forall t$. *The equilibrium price on the secondary market is* $p^U = \alpha\theta_l$, $\forall t$.

Notice that the monopoly price is increasing in both the current and future equilibrium price on the secondary market.

Oligopoly. G firms that want to sustain the monopoly outcome as a subgame-perfect equilibrium in grim trigger strategies will charge price p^m in every period as long as no firm undercuts this price. When a firm does undercut, they set a price equal to c from that period on. Recall that the demand function depends on the price history of new units, the stock of used goods available and the present and future price of used goods. Thus, a forward-looking consumer anticipating a price war in the next period will update his expectation regarding

[6] I consider a simple framework where consumers' decision is not state-dependent in order to focus on the central result of the present paper. Considering a more complicated model with state-dependent decisions will not add any insight. In such a model both intertemporal substitution and resale value component of demand will strengthen firms' ability to collude.

the equilibrium price on the secondary market in the period following defection. A price war will lead to overproduction of new goods and it might depress the demand for used goods and drive down their equilibrium price. A lower expected price for used goods will reduce the demand for new goods in the defection period. Again, part of the punishment may be effected immediately, and this facilitates the monopoly-price outcome.

Lemma 2 *After a defection, the equilibrium price on the second-hand market following a grim trigger is positive if* $c > (1-\alpha)\,\theta_l$.

In the standard repeated Bertrand game, setting future price to marginal cost is the maximum punishment that can be inflicted on a deviator. A future price below marginal cost would not have a further impact, because the deviator would simply withhold production. However, in a durable-goods setting, the market price anticipated by consumers for the period following a unilateral price cut would affect demand in the defection period, i.e. an anticipated price below marginal cost would reduce consumers' willingness to pay for new goods. Because of this effect, absent in repeated games, even harsher punishments than grim trigger strategies are possible and profits in the defection period can be pushed below what they would have been under grim trigger strategies.

Define *sharp* grim trigger strategies as follows: initially all the firms set p^m and do so as long as no firm sets a lower price. In the period after deviation there will be a $\zeta^* \in [0, c)$ such that firms post a punishment price for new units $p^P_{t+1} \leq \zeta^*$[7] to induce $p^U_{t+1} = 0$.[8] Notice that driving the expected price to zero completely removes the resale value component of demand in the defection period. Because profit after the defection period may be negative, I assume that, in order to induce a Nash equilibrium in the stage game of that period, all firms play the collusive price p^m in every period, starting from $t+2$ with probability μ, and price at the marginal cost, c, with probability $1-\mu$. I assume (as is common in the repeated game literature) that μ is public. If any firm does not obey the punishment pricing, the others restart the punishment sequence. There is no incentive for any firm to deviate from the punishment pricing.

Using the sharp grim trigger strategy, the expectation regarding future prices will be

$$\begin{aligned} p^N_{t+1} &= p^m \text{ and } p^U_{t+1} = a\theta_l \text{ if } p^N_t = p^m \\ p^N_{t+1} &= p^P_{t+1} \text{ and } p^U_{t+1} = 0 \text{ if } \ p^N_t \neq p^m \end{aligned} \tag{2}$$

The sharp grim trigger strategy supports p^m as a subgame perfect equilibrium if and only if the following two conditions hold:

[7] A grim trigger strategy will be sufficient to drive $p^U_{t+1} = 0$ as long as $c \leq (1-\alpha)\,\theta_l$. As from lemma 2 the equilibrium price on the secondary market will be $p^U = \max\{\frac{c-(1-\alpha)\theta_l}{(1+\delta)}, 0\}\ \forall \tau \geq t+1$.

[8] Notice that in particular $p^U_{t+1} = 0$ if $p^P_{t+1} = 0$

$$\Pi_t^D + \delta_f \frac{\Pi_{t+1}^P}{G} + \mu \cdot \delta_f^2 \sum_{\tau=2}^{\infty} \delta_f^{\tau-2} \frac{\Pi_{t+\tau}^m}{G} \leq \frac{\Pi^m}{G\,(1-\delta_f)} \tag{3}$$

$$\frac{\Pi_{t+1}^P}{G} + \mu \cdot \delta_f \sum_{\tau=2}^{\infty} \delta_f^{\tau-2} \frac{\Pi_{t+\tau}^m}{G} = 0 \tag{4}$$

The first term in condition (3), Π_t^D, is the profit that the defector gets in the defection period (i.e. $\Pi_t^D = ((1-\alpha)\,\theta_h + \alpha\theta_l - c)\,n_h)$.[9] As described in (2), consumers see a price p_t^N lower than p^m and so expect the price of used goods to be zero tomorrow which reduces their willingness to pay for new units in the defection period. The second term, $\frac{\Pi_{t+1}^P}{G}$, is negative and is the loss supported by each firm in the first punishment period. The last term on the left-hand side is the share of the monopoly profit earned (with probability μ) after the punishment period.[10] On the right-hand side is the share of the (steady-state) profit that the defecting firm would have earned if it had not defected, i.e. $\Pi^m = ((1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c)\,n_h$. In order to obtain subgame perfection such severe punishment should be incentive-compatible, and this is guaranteed by (4). The first term on the left-hand side of (4) represents the profit for each firm during the first punishment period, and the sum of discounted profits thereafter, evaluated from the first period of obeying the punishment. Because the first term is (possibly) negative, condition (4) requires this present value to be non-negative; otherwise, firms would do better by pricing at marginal cost forever (or by leaving the market). The same condition requires the left-hand side also to be non-positive in order to punish the defector more effectively.[11] In the present framework where there is dependence between the periods, sharp grim trigger strategies minimize the incentive to defect:

Proposition 2 *Sharp grim trigger strategies maximize the range of discount-factor values over which collusion is sustainable.*

[9] The defector has no incentives to sell the new units to all consumers.

[10] Notice that the profit in each period depends on the number of new goods sold in the previous periods. Hence in period $t+2$, the monopoly profit after a defection is not equal to the monopoly profit in the steady-state. There will be an excess supply of used goods that will affect the equilibrium price in the second-hand market and consequently in the primary market. However from $t+3$ onward the monopoly profit will coincide with the steady state one. With a slight abuse of notation in equation (3) and (4) I have put a time index to the whole stream of profits that should be read as above.

[11] Lemma 4 in the appendix provides the necessary and sufficient conditions that guarantee the existence of the sharp grim trigger strategies.

Proposition 3 *The monopoly price p^m is sustainable as an equilibrium in an oligopoly if $\delta_f \geq \delta_f^* = 1 - \frac{1}{G\gamma^*}$. δ_f^* is a decreasing function of the quality of the used goods, α, and of consumers' discount factor, δ, and is an increasing function of the distance of consumers' valuation from quality, $\theta_h - \theta_l$.*

This proposition shows that a higher quality of used goods implies a higher resale value component and a harsher punishment in case of defection. This finding suggests that an increase in the number of competitors entering the market might induce firms to coordinate[12] and increase the durability of goods in order to enforce collusion. The literature on investment in R&D[13] suggests that competition among firms leads to an overinvestment in R&D with respect to the level that maximizes the profitability of a group. Each firm takes into account the benefits from its investment, but not the positive externality due to the reduction in the value of rivals' investment. The results in the model seem to confirm these findings: the possibility of collusion might lead to an over-investment in durability with respect to the level that maximizes monopoly profit. If the number of competitors continues to increase, firms will eventually end up choosing a level of durability greater than the socially optimal level.

More generally, there are two forces that will influence the choice of the durability of the good and these do not necessarily move in the same direction. From the previous discussion, the incentive for firms to increase value α is clear. However, increasing the quality of the used good might reduce the level of monopoly profit, depending on the relative importance of the resale component versus the substitution component of demand. Hence, collective incentives to increase the durability of the good may not be aligned with the monopoly incentive to increase profit.

Proposition 3 also suggests that a wider difference in consumers' valuation of quality makes the resale effect relatively less important for high-valuation consumers' demand for new goods (the equilibrium price on the secondary market is a function of θ_l) and the punishment less effective. Finally, notice that when consumers are sufficiently patient, they value the resale component more highly in the decision to buy new products, so that the expectation of a price war will induce a considerable adjustment in their willingness to pay for new goods. This implies that lower deviation payoffs and collusion are therefore easier to enforce.

In the above analysis I consider the situation without transaction costs (T), but it is not difficult to extend the analysis to include transaction costs in the secondary market. For sufficiently small transaction costs, the second-hand market is still open. If the transaction costs are borne by the consumers who buy used goods, it is intuitive to derive that the

[12] Given that firms produce a homogenous good.

[13] See Reinganum (1989), Hirshleifer and Riley (1979), Waldman (2003) for a survey.

equilibrium price of used units is a decreasing function of the transaction cost ($p_t^U = \alpha\theta_l - T$, $\forall t$). A marginal increase in transaction costs will reduce the resale value effect and the ability to punish a defector ($\frac{\partial\gamma}{\partial T} > 0$). Hence the presence of transaction costs will not only reduce a firm's profitability,[14] but also its ability to collude. This result is in line with the main findings of the present work: firms may prefer to have an active and frictionless second-hand market.

3 Closing the second-hand market

The used good is a cheap substitute for the new good. Thus, closing the used good market may in principle be a profitable decision for a monopolist. However, as I described in the introduction there are many example, in whiche manufacturers seem to intervene in the opposite direction. In this section, I discuss the monopolist incentives and the collective incentives to interfere with transactions in the secondary market. In particular, I shall only discuss the case in which firms choose whether to close the used market entirely or to keep it open. I leave the discussion about different strategies affecting the second-hand market to the next section. Focusing on this case only will give me the opportunity to compare and discuss how the presence of the second-hand market may facilitate collusion with respect to existing literature (Gul, 1987 and Ausubel and Deneckere, 1987) where the good is durable and consumers may make intertemporal substitution but there is no second-hand market.

Consider the same assumption as before wherein the good lasts two periods and it depreciates in the second period. Closing the used market means that consumers can either scrap or keep their used units but not buy and sell used goods (for example transaction costs are so large as to prevent consumers from exchanging used goods). Without the second-hand market, consumers can either buy a new good every two periods (keeping the used good for one period), or they can buy a new good every period and scrap the used good.

Lemma 3 *In the steady-state, consumers always prefer buying the new good every two periods if* $p^N > (1-\alpha)\theta_h$.

Consider first how closing the used market affects monopoly incentives. Suppose the monopolist is producing a steady-state flow of output in each period and always finds it profitable to sell the good only to the high type. There are two possible scenarios to consider. The monopolist extracts all the rents from the high types by charging the monopoly price $p^m = (1 + \alpha\delta)\theta_h$; by lemma 3, consumers purchase the new good every two periods. Thus a steady-state in the market is obtained when the population is split into two identical copies

[14] See for example Porter and Sattler (1999) or Anderson and Ginsburgh (1994) for a formal derivation of the equilibrium with transaction costs, and Schiraldi (2008) for an empirical analisis.

of mass 1/2, one purchasing every odd period, the other purchasing every even period. Alternatively the monopolist charges a lower price and sells the new unit to all consumers at price $p^m = (1-\alpha)\theta_h$. Consumers buy the new product every period and scrap the used one. The profit in each period is respectively $((1+\alpha\delta)\theta_h - c)n_h/2$ and $((1-\alpha)\theta_h - c)n_h$. The first strategy is better than the second if $c > \theta_h(1-2\alpha-\alpha\delta)$, which is always the case if $\alpha > \frac{1}{2+\delta}$.

Proposition 4 *The monopolist maximizes his profit by closing the second-hand market if* $c > (1-\alpha)\theta_h + \alpha(1+\delta)(2\theta_l - \theta_h)$.

If the monopolist maximizes his profit by selling the new goods to all consumers every period, then the price and consequently the profit are lower than the case with an active second-hand market. With a second-hand market, the monopolist sells to all high types in each period. If the monopolist maximizes his profit by charging $p^m = (1+\alpha\delta)\theta_h$ then the monopoly price is higher without an active secondary market. However, the monopolist may achieve a higher profit with an active second-hand because of a more efficient allocation of new and used goods among consumers equivalent to an indirect form of price discrimination. Whether the total profit is higher or lower depends on the level of the marginal cost, the difference in willingness to pay between high and low types and the quality of the used good. In particular, monopoly profit is always higher with the second-hand market than in the alternative of selling to all consumers with high-valuation in every period at the price $(1-\alpha)\theta_h$.

Oligopoly. Consider now a setting with G firms that want to sustain the monopoly outcome as a subgame-perfect equilibrium in (*sharp*) grim trigger strategies. As in Gul (1987) and Ausubel and Deneckere (1987) the possibility of intertemporally substituting consumption, i.e. deciding when to buy durable goods based on the expected price for new goods in the future, constrains the maximum price that a defector can charge in the defection period, hence it reduces the prize that the defector could get by deviating. Consumers will forgo the utility of buying a new good today if they expect its price to be substantially lower tomorrow. The intertemporal link in demand introduces scope for harsher punishments in case of defection as with the second-hand market. However, the mechanism through which the extra punishment operates is different with or without the second-hand market, and consequently has different implications in terms of the possibility to enforce collusion in equilibrium.

Proposition 5 *The range of discount-factor values over which collusion is sustainable is maximized with an active second-hand market if and only if* $c > (1-\alpha)\theta_h$ *or* $c < \theta_h(1-2\alpha)$.

Collective incentives, i.e. the ability of firms to sustain collusion, will depend on the level of marginal cost. If the marginal cost is high (higher than $(1-\alpha)\theta_h$) the mark-up with the secondary market is lower than without and a drop in price will have a relatively bigger effect on profit in the defection period ($\frac{(1-\alpha)\theta_h+\alpha\theta_l-c}{(1-\alpha)\theta_h+\alpha(1+\delta)\theta_l-c}$ vs. $\frac{\theta_h-c}{(1+\alpha\delta)\theta_h-c}$). Hence, collusion will be sustained under a broader range of parameter values with the secondary market. In particular, if the marginal cost is higher than the price minus the resale value components (i.e. $(1-\alpha)\theta_h+\alpha\theta_l$), then the defector gets zero profit in the defection period with an active second-hand market. The situation is opposite for intermediate values of the marginal cost. Notice that as the marginal cost decreases, the monopoly profit with a secondary market is likely to be higher than without.

Consider the case of no second-hand market. If the quality of the used good is low enough ($\alpha < 1/2$) consumers have a low incentive to forgo the utility from buying a new good today if they have no good. Moreover, consumers with a used good and without the possibility to resell it will be tempted to buy a new good and scrap the used one. If the marginal cost is also low then the defector will further lower the price in the defection period to sell the good to all consumers and maximize profit. In such a situation the punishment inflicted on the defector in the defection period is lower than with a secondary market and so the ability to collude decreases. In particular, if the marginal cost is lower than $(1-2\alpha-\alpha\delta)\theta_h$, firms achieve the highest collusive profit by selling the new good to all consumers every period, but consumers no longer have any incentive to make intertemporal substitutions. At this level of marginal cost, firms find it profitable to reduce the price charged to consumers so that they will always buy a new good even if they have a used one (which they scrap). The lower unitary mark-up is compensated by the possibility of selling new goods more frequently. The lack of the intertemporal link in demand destroys completely the possibility of extra punishment in the defection period.

The key element of the previous argument is that the leverage of firms to sustain collusion by punishing the defector in the defection period itself is linked with the ability of consumers to intertemporally substitute consumption of the durable good. Such an incentive decreases with the utility that consumers get from having a used good. The ability to sustain collusion with a second-hand market instead decreases with the equilibrium price for used goods. Even if both are affected in the same way by the quality of the used goods, they may determine different responses by the firms which differentially affect the ability to collude. Moreover, there are elements that affect either the used price on the second-hand market or the ability to intertemporally substitute consumption but not both. For example the presence of transaction costs if it does not prevent transactions on the second-hand market will only reduce the equilibrium price of used goods and vice-versa low utility from keeping a used good could be determined by factors that will not affect the equilibrium price in the secondary market. Consider, for example, the situation in which the high types get positive utility from having a new good but have no utility from having a used one (for any value of

α arbitrary close to 1), whereas the low types get positive utility from both new and used goods. A real-world example for this assumption could be the automobile market where high types and low types are located in two different countries E and I. The cars are produced only in E. The country with high types has very stringent automobile safety and emission standards that make the use of used cars extremely costly, but there are no such costs in the country with low types.[15] Assume for simplicity that the net utility from having a used car is zero or negative. Hence, consumers in E have incentives to buy a new car every period.

Corollary 1 *If there is no trade between the two different types of consumers, the monopoly profit is lower as well as is the ability to enforce collusion.*

Without the possibility of trading the goods between the two countries, firms cannot increase their profit using the second-hand market as a form of indirect price discrimination. Moreover, high-valuation consumers in E have no incentive to intertemporally substitute consumption reducing the extra punishment in the defection period which strengthens the ability to collude in a durable good environment. Notice that the gain from trade does not derive from the presence of different consumer tastes (which could also be the same), but from the existence of asymmetric automobile safety and emission standards. No restriction on the marginal costs are necessary.

4 Strategies affecting the second-hand market

The presence of the internet, lower transportation costs, and trade agreements have expanded the scope for a second-hand market by reducing transaction costs. When firms cannot prevent a priori the possibility of reselling used goods on a decentralized market, it becomes relevant to study how they can otherwise affect the secondary market and hence their profits as well the ability to collude by using different strategies.

In particular, I analyze three of the most relevant policies used in real-world practice: leasing policy, buy-back policy and transferable warranty. The leasing policy allows the manufacturer to directly control for the presence of used goods like automobiles in the market (without any additional cost) and consequently to increase the monopoly profit. With leasing contracts, the manufacturer sells only the flow of service derived from products for the length of the contract period. In such a situation there is practically no second-hand market because no new durable goods are sold on the primary market. However, the policy lessens the ability of firms to sustain collusion. It follows that oligopolistic collective incentives lead in the opposite direction from individual incentives. Firms that interact in

[15] See Clerides and Hajinyiannis (2008) for a more comprehensive discussion about the role of safety and emission standards on monopoly profit.

a Bertrand fashion might therefore prefer the selling-only policy to the leasing strategy in order to collect a positive profit. The buy-back policy involves a fixed amount of money offered by manufacturers (and usually determined in a contract) to buy back goods from consumers willing to trade them in and buy new ones. The incentive for firms is to stimulate demand for new products by increasing the resale value effect and making used goods a more expensive substitute for new ones. With the buy-back, the manufacturer is still able to control the number of used goods available (at the cost of buying them back), but leaves the second-hand market active. This preserves the intertemporal feature of demand for new goods and makes collusion easier to enforce. A buy-back policy may not only increase profit with respect to selling, but it always strengthen collusion. A transferable warranty is also a means to stimulate demand if it increases the resale value effect on demand relative to the substitution effect. With the warranty, the manufacturer freely guarantees a certain level of quality for the used goods (by fixing it if faulty). The warranty increases the profit differential in the defection period because it increases the level of the resale value component and enhances the ability to collude. The warranty influences the price of used goods through their intrinsic quality whereas buy-back affects it through market mechanisms. Whereas leasing and buy-back are substitute policies, a warranty may be offered along with either of them.

4.1 The Leasing Policy

Waldman (1997) and Hendel and Lizzeri (1999a) show how the monopolist benefits most by leasing new goods rather than selling them.[16] Leasing contracts achieve the result of no active second-hand market because firms retain ownership of new goods. With leasing contracts, the manufacturer is able to sell only the flow of service derived from products for the length of the contract period. In such a situation there is no second-hand market because no new durable goods are sold on the primary market. Hence, leasing policy breaks dynamic investment considerations to consumption decisions and lessens firms' ability to collude. Therefore collective and individual incentives move in opposite directions.

Monopoly. We start the analysis by looking at monopoly behavior. Suppose that the monopolist decides to lease new goods for one period (instead of selling them) in order to gain additional power in the used market. The monopolist retains ownership of the goods such that they have to be returned at the end of the contract. The consumer's decision to rent a new product does not depend on its resale value, but rather only on the substitution

[16] This result is obtained within a simple framework where there are no transaction costs, no lemon problems on the second-hand market or moral hazard behavior. As described by Hendel and Lizzeri (2002) and Huang, S., Yang, Y. and K. Anderson (2001), in a more realistic model with transaction costs and/or hidden information, firms prefer to offer a mix of leasing and sales contracts.

effect, i.e. the possibility of renting used goods instead of new ones. Consumer θ_i determines his optimal consumption choice by solving:

$$\max\{\theta_i - l_t^N, \alpha\theta_i - l_t^U, 0\} \tag{5}$$

Of course the demand for new goods has no dynamic features.

Proposition 6 *The monopolist always maximizes his profit by leasing new goods rather than selling them.*

Oligopoly. We can define the trigger strategies supporting a constant collusive leasing-price pair $\{l^N, l^U\}$ (or l^N only if no used goods are rented) as follows: all firms set the price pair $\{l^N, l^U\}$ (or l^N) in the initial period and continue to do so in all future periods as long as no firm undercuts these prices. After a defection firms set the leasing price for new goods equal to c and the leasing price for used goods equal to zero. Consumers will first lease the good that delivers the highest utility. If they prefer the used good (for a given set of parameters), they will lease all the used units available (on a first-come-first-served basis) and the remaining consumers will lease the new ones.[17] Independently of the number of new or used goods leased after a defection, the firms' profit will always be zero. The leasing-only policy always undermines firms' ability to sustain collusion.

Proposition 7 *The leasing-only policy always raises the minimum discount-factor value that supports collusion.*

The above result suggests that, even if leasing achieves a higher (monopoly) profit than sales, at the same time it reduces the range of parameter values over which collusion can be sustained in equilibrium. As it is clear from equation (5) there is no extra punishment that can be inflicted on a defector in the defection period because there is no resale value component in the demand of new goods. Therefore, the minimum discount-factor value that supports collusion is $\delta_f^l = 1 - \frac{1}{G}$ as in the standard case with no durable goods. It follows that oligopolistic collective incentives lead in the opposite direction from individual incentives. Firms that interact in a Bertrand fashion might therefore prefer a sales-only policy to a leasing strategy in order to collect a positive profit.

4.2 The Buy-Back Policy

Manufacturers can also increase their market power by employing a buy-back policy. As a real-world practice, manufacturers offer a fixed amount of money to buy back cars from

[17] Notice that the number of used goods available is constrained by the number of new units leased previously.

those consumers willing to trade them in and buy new ones. The idea behind this policy is that firms interfere with the second-hand market by raising the demand of used goods and consequently their equilibrium price. The incentive for firms is to increase the willingness to pay for new products by increasing the resale value effect and reducing the substitution effect. With the buy-back, the manufacturer is still able to control the number of used goods available, but leaves the second-hand market active. This policy is costly to implement and may not necessarily increase monopoly profits. However, it preserves the intertemporal feature of demand for new goods and always strengthens the ability to enforce collusion.

Monopoly. The monopolist can try to increase profit by interfering with the second-hand market and to gain additional market power by using the buy-back policy. The firm commits to buying and scrapping used cars for a given price. The equilibrium with commitment can be obtained as a subgame perfect Nash equilibrium in which the monopolist establishes a reputation for eliminating the second-hand market. When the monopolist achieves a higher profit, the threat of moving to an equilibrium with an active second-hand market prevents him from deviating by not repurchasing the used goods (see Waldman, 1997). For simplicity, I assume that the monopolist can commit to a buy-back price in order to compute the monopoly outcome that firms can support as a subgame perfect equilibrium in grim trigger strategies. The commitment can easily be sustained because in real world practice the buy-back price is written into the contract signed by both parties at the time of a new purchase.

If the monopolist decides to apply the policy, the price (b^U) offered to buy the used cars back cannot be lower than the market price of used goods. Consumer θ_i determines his optimal consumption choice by solving:

$$\max\{\theta_i - p_t^N + \delta b^U, \alpha\theta_i - b^U, 0\} \tag{6}$$

where b^U is the price at which a firm commits to buy back used units.

Proposition 8 *The monopolist maximizes profit with the buy-back by choosing* $b^m = \alpha\theta_h$ *and* $p^m = (1 + \alpha\delta)\,\theta_h$ $\forall t$. *In equilibrium all the high-valuation type consumers buy new goods in every period and trade them in in the following period.*

- *The monopoly profit with buy-back is higher than selling alone if* $\theta_h > \frac{1+\delta}{\delta}\theta_l$.
- *The monopoly profit with buy-back is always lower than leasing.*

This result shows that the monopolist can profitably interfere with the second hand market. The role of the buy-back is to influence positively the resale value effect by increasing the price of used cars. The policy is profitable if there is a substantial difference in consumers' valuations of the quality of the goods, so that the cost of implementing the policy is lower than the benefit.[18]

Oligopoly. Firms can collude and sustain the monopoly buy-back equilibrium outcome using sharp grim trigger strategies. Initially all firms ask p^m and offer to buy back used units at b^m and continue to do so as long as no firm defects. In the period after deviation there will be a $\zeta^b \in [0, c)$ such that firms post a punishment price for new unit $p^P_{t+1} \leq \zeta^b$ to induce $p^U_{t+1} = 0$ and the buy back price is no longer offered. As described in the previous section, because profit after the defection period may be negative in order to induce a Nash equilibrium in the stage game of that period, I assume that with probability μ all firms play the collusive equilibria offering $\{p^m, b^m\}$ from period $t+2$ onwards and with probability $1-\mu$ they price at the marginal cost, c, without the buy-back policy. If any firm does not obey the punishment pricing in a punishment period, the others restart the punishment sequence.

Using the sharp trigger strategy, expected future prices will be

$$\begin{aligned} p^N_{t+1} &= p^m \text{ and } b^m = a\theta_h \text{ if } p^N_t = p^m \\ p^N_{t+1} &= p^P_{t+1},\ p^U_{t+1} = 0 \text{ if } \ p^N_t \neq p^m \text{ and } b = 0 \end{aligned} \tag{7}$$

Notice that in the defection period the firm that under cuts p^m continues to offer the same buy-back, any further reduction in the buy-back price will imply a corresponding reduction in the under-cutted price. Consumers always have the possibility of selling the good on the used market or to other firms. The buy-back policy always enhances firms' ability to enforce collusion with respect to a selling-only policy.

Proposition 9 *The buy-back policy always reduces the minimum discount-factor value that supports collusion.*

Similar necessary and sufficient conditions can be derived for the existence of the sharp grim trigger strategy that supports the monopoly buy-back equilibrium outcome as subgame perfect equilibrium.

The buy-back policy always expand the scope for collusion and it might increase profit with respect to selling. Hence, collective and individual incentives are aligned if buy-back is more profitable than selling, i.e. $\theta_h > \frac{1+\delta}{\delta}\theta_l$, and they diverge otherwise. The results imply that to sustain collusion and share a positive profit, firms may use this policy even if it reduces the monopoly profit (as long as it is strictly positive).

[18] Notice that having no used goods available is a particular feature of the model with two types of consumers. With a continuum distribution of consumers, used goods are always traded on the second-hand market (Schiraldi, 2006).

4.3 Transferable Warranties for Used Goods

The scope for warranty exists in a world where there is uncertainty about the value of used goods. As I discussed in the introduction, car and computer manufacturers provide free warranties for used goods which are transferable between owners in order to improve transactions on the second-hand market. Incentives to offer transferable warranties may be twofold. First, if the resale value effect dominates the substitution effect and the cost of implementing the policy, firms can achieve a higher profit by increasing the average quality of used goods. Moreover, and more central to my analysis, oligopolistic firms always have an incentive to offer a warranty in order to enforce collusion (charge the monopoly price). By increasing the average quality of used goods, firms increase the punishment that they can inflict on a defector in the defection period, making defection itself less profitable.

Let me introduce uncertainty about the quality of the used good by assuming that quality of the used good is a random variable equal to $\omega \in (0,1)$ with probability $\varphi \in (0,1)$ and 0 with probability $1-\varphi$. Let $\alpha = \varphi\omega$ be its expected value. The value of the used goods is realized after the transaction so that there are no concerns about asymmetric information. Each firm may offer the following warranty when they sell a new product: if the quality of the used good in the second period is revealed to be 0, they can reinstate the quality ω. Firms pay a cost k for each product fixed.[19] Consumer behavior will not change and in particular the equilibrium price on the second-hand market will be $p_t^U = \alpha\theta_l$, if there is no warranty and $p_t^U = \omega\theta_l$ otherwise. Similarly the equilibrium price in the primary market will be respectively $p^m = (1-\alpha)\theta_h + \alpha(1+\delta)\theta_l$ and $p^\omega = (1-\omega)\theta_h + \omega(1+\delta)\theta_l$.

Monopoly. The monopolist has incentives to offer a transferable warranty along with the new good when (a) it increases the overall willingness to pay, i.e. it increases the resale value effect by more than the substitution effect and (b) the increase in price that follows from the increase in the willingness to pay is higher than the expected cost of fixing the good. More formally:

Proposition 10 *The monopolist maximizes his profit by offering transferable warranties if and only if* $\omega(\theta_l(1+\delta) - \theta_h)(1-\varphi) - k\varphi \geq 0$.

Oligopoly. Firms can collude and sustain the monopoly price, p^ω, with warranty in equilibrium using sharp trigger strategies.[20] Initially all firms ask p^ω and offer a warranty and they continue to do so as long as no firm defects. Similarly as before all firms post a price $p_{t+1}^P < c$ to induce $p_{t+1}^U = 0$ and no warranty is offered: from period $t+2$ onwards all

[19] Warranties are equivalent to improvements in the quality of a used good which is implemented with a linear cost technology.

[20] Notice that p^ω is not necessarily greater than p^m because the substitution effect may dominate the resale value effect. Nevertheless firms may prefer p^ω to sustain collusion.

firms play the collusive price p^{ω} with probability μ and with probability $1-\mu$ they price at the marginal cost, c, without a warranty. If any firm does not obey the punishment pricing in a punishment period, the others restart the punishment sequence.

As before, using the sharp trigger strategy the expectation concerning future prices will be

$$\begin{aligned} p_{t+1}^{N} &= p^{\omega} \text{ and } p_{t+1}^{U} = \theta_l \text{ if } p_t^N = p^{\omega} \\ p_{t+1}^{N} &= p_{t+1}^{P} \text{ and } p_{t+1}^{U} = 0 \text{ if } \; p_t^N \neq p^{\omega} \end{aligned} \tag{8}$$

The warranty always enhances firms' ability to sustain collusion.

Proposition 11 *The warranty always reduces the minimum discount-factor value that supports collusion.*

As for the buy-back policy collective and individual incentives are aligned if offering a warranty is profitable, i.e. $\omega\left(\theta_l\left(1+\delta\right)-\theta_h\right)\left(1-\varphi\right)-k\varphi \geq 0$, and they diverge otherwise. This suggests that if the number of competitors is such that, given the discount factor δ_f, the monopoly outcome without warranty cannot be sustained as a subgame perfect equilibrium in sharp grim trigger strategies $(\delta_f^{\omega} < \delta_f < \delta_f^{*})$[21], firms have an incentive to offer a warranty and charge p^{ω}, even if it reduces the monopoly profit (as long as it is strictly positive), in order to collect a positive profit. Competition forces them to offer a warranty for used goods (or to use a buy-back policy) even if this is not optimal from a monopolist's point of view.

Similar implications as in the warranty case apply in the decision of choosing the quality ex-ante as also discussed at the end of section 2. The two arguments are complementary because firms can choose either the quality ω or the degree of uncertainty φ. There are several explanations of why a firm might prefer to offer a warranty rather than to eliminate uncertainty, i.e. $\varphi = 1$. First, it might be cheaper to offer a warranty and to fix the good than to choose no-uncertainty ex-ante. Second, uncertainty about the quality may not be related to the nature of the good, but to the use made of the good by consumers.

5 Conclusion

The aim of the present work is to analyze how the second-hand market influences the ability of firms to sustain collusion over time. I study firms' preference for having an active second-hand market and whether policies that affect the functioning of the second-hand market strengthen collusion.

[21] It is straightforward to see that leasing is not sustainable as collusive equilibrium either.

The intuition is that the prospect of obtaining a high price on a second-hand market increases demand for new goods. By threatening to price at equal to or even below marginal cost in the post-deviation period, competing firms can reduce or remove the resale-value component of demand for new goods in the current period. A reduction in resale value will also reduce the profit from new goods in the defection period. In this view, firms can implement different policies directed to strengthen sales on the secondary market so as to increase the threat of punishment in case of defection.

The model predicts that for collusive purposes having an active second-hand market is preferable every time the marginal cost of production is either high or low and there is a sharp reduction in the quality of the durable good over time. More generally, the second-hand market will be preferred for collusive purposes whenever consumer utility from keeping the used good is low because it is costly to keep the good over time. Hence, I study the incentive to interfere with an active second-hand market. In particular, I discuss how a leasing policy, by eliminating the dynamic component of demand, reduces the range over which collusion can be sustained, but increases monopoly profit. Buy-back policy and warranty coverage favour collusive behavior by increasing the market value of used goods (these policies increase either the price or the quality of the used units) but they do not necessarily generate a higher level of profit.

I believe that the explanation provided in this paper suggests some further insights that can illuminate durable-goods manufacturers' behavior and further explain how the second-hand market influences the primary market and interacts with it.

Appendix

Proof Lemma 1. *Each consumer θ_i solves in each period the optimal consumption problem given the prices of new and used goods which can be formulated using Bellman's equation. There are two relevant cases:*

- – *If consumer i has no good at the beginning of the period then he can choose to buy a new good, a used good or to be without any good:*

$$V_{it}(0) = \max\{\theta_i - p_t^N + \delta V_{it+1}(1), \alpha\theta_i - p_t^U + \delta V_{it+1}(0), \delta V_{it+1}(0)\} \tag{9}$$

- – *if he already owns a good then he can choose to sell the used good on the secondary market and buy a new good or to be without any good or he can choose to keep the used good:*

$$V_{it}(1) = p_t^U + \max\{\theta_i - p_t^N + \delta V_{it+1}(1), \alpha\theta_i - p_t^U + \delta V_{it+1}(0), \delta V_{it+1}(0)\} \tag{10}$$

$$\Leftrightarrow V_{it}(1) - p_t^U = \max\{\theta_i - p_t^N + \delta V_{it+1}(1), \alpha\theta_i - p_t^U + \delta V_{it+1}(0), \delta V_{it+1}(0)\}$$

(9) and (10) imply $V_{it}(1) - p_t^U = V_{it}(0)$. Using the result in (9) or (10), it follows that the consumer maximization problem is independent of his endowment:

$$V_{it}(0) = \delta V_{it+1}(0) + \max\{\theta_i - p_t^N + \delta p_{t+1}^U, \alpha\theta_i - p_t^U, 0\}$$

Proof Proposition 1. *The monopolist sells to high-valuation types only; there will be n_h used goods available on the secondary market in every period. Given that $n_h < n_l$, high-valuation types capture the whole rent from low-valuation types. The competitive price on the secondary market is $p^U = \alpha\theta_l\ \forall t$. The maximum price that the monopolist can charge must leave the high-valuation types indifferent as to whether to buy a new good or keep the used good. Therefore*

$$\theta_h - p_t^N + \underbrace{\delta p_{t+1}^U}_{\text{Resale Value effect}} = \underbrace{\alpha\theta_h - p_t^U}_{\text{Substitution effect}}$$

then

$$p_t^N = (1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l.$$

Proof Lemma 2. *There are two relevant cases to consider:*

- *if $c > (1+\alpha\delta)\,\theta_l$ low types will never find it optimal to buy new goods and the equilibrium price on the secondary market will still be $\alpha\theta_l$.*

- *if* $c \leq (1+\alpha\delta)\,\theta_l$, *the maximum price that high types can charge on the secondary market must leave low-valuation consumers indifferent between buying the new good and keep it or buying the used good every period. In particular assume that low-valuation consumers buy used goods if available when they are indifferent. Then the continuation values in these two scenarios are* $V_1 = \frac{(1+\alpha\delta)\theta_l - c}{1-\delta^2}$ *and* $V_2 = \frac{\alpha\theta_l - p^U}{1-\delta}$ *respectively. Hence if* $c = (1+\alpha\delta)\,\theta_l \Rightarrow p^U = \alpha\theta_l$ *and if* $c < (1+\alpha\delta)\,\theta_l \Rightarrow p^U = \frac{c-(1-\alpha)\theta_l}{1+\delta} > 0$ *by assumption a2.*

Lemma 4 *The existence of sharp grim trigger strategies is guaranteed by* $\Pi_t^D \leq \dfrac{\Pi^m}{G\,(1-\delta_f)}$ *and* $\dfrac{\delta_f^2}{1-\delta_f}\,\dfrac{\Pi^m}{-\Pi_{t+1}^P} > \dfrac{n_l+n_h}{n_h}$

Proof Lemma 4. *The first inequality, the necessary condition, is derived by substituting equation (4) in (3). The sufficient condition holds because of the following reasoning. Notice that the left-hand side of (4) is an increasing function* f *of* $\mu \in [0,1]$, *with* $f(0) = \frac{\Pi_{t+1}^P}{G}$ *and* $f(1) = \frac{\Pi_{t+1}^P}{G} + \delta_f \sum_{\tau=2}^{\infty} \delta_f^{\tau-2} \dfrac{\Pi_{t+\tau}^m}{G}$. *By the intermediate value theorem,* $f(0) < 0 < f(1)$ *is sufficient for the existence of a probability* $\mu \in (0,1)$ *such that condition (4) holds.* $f(0) < 0$ *is satisfied by construction and* $f(1) = \frac{\Pi_{t+1}^P}{G} + \dfrac{\delta_f}{G}\Pi_{t+2}^m + \dfrac{\delta_f^2}{(1-\delta_f)G}\Pi_{t+3}^m \geq \dfrac{((1-\alpha)\,\theta_l - c)\,(n_l+n_h)}{G}$

$$+\max\left\{0, \frac{\delta_f}{G}((1-\alpha)\,\theta_h + \alpha\delta\theta_l - c)n_h\right\} + \frac{\delta_f^2}{(1-\delta_f)G}((1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c)n_h > 0^{22}$$

$$\Longleftrightarrow \frac{\delta_f^2}{1-\delta_f}\frac{((1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c)}{-((1-\alpha)\,\theta_l - c)} > \frac{n_l+n_h}{n_h}.$$

Proof Proposition 2. *Condition (4) assures that the present discounted payoff after a defection is equal to zero. This is the maximum credible punishment that can be inflicted through the continuation payoff after a defection and still satisfies individual rationality*[23]. *By substituting equation (4) in (3), the minimum discount factor,* δ_f^*, *that sustains the equilibrium collusion is given by:*

$$\mathit{\Pi}_t^D \leq \frac{\Pi^m}{G\,(1-\delta_f)} \Rightarrow \delta_f \geq \delta_f^* = 1 - \frac{1}{\gamma^* G}$$

δ_f^* *is decreasing in* γ^* *where* $\gamma^* = \frac{\Pi_t^D}{\Pi^m} = \dfrac{(1-\alpha)\,\theta_h + \alpha\theta_l - c}{(1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c}$. *Given that* Π^m *is the monopoly profit, the minimum* δ_f^* *is achieved by minimizing* Π_t^D. *From lemma 1 and*

[22] Notice that in the period after the punishment there is an excess supply of used goods so the equilibrium price on the second-hand market is zero.

[23] Firms always have the possibility of not producing and receiving zero. Zero profit is also the outcome of the one-period Bertand-Nash equilibrium.

proposition 1, Π_t^D *is affected by firms' future behavior through the resale value component of the demand. Hence it is minimized if* $p_{t+1}^U = 0$*. By sufficiently lowering the price of new goods (possibly below the marginal costs) in* $t+1$*, all consumers will prefer buying new products. Therefore the excess supply of used goods will drive* p_{t+1}^U *to zero.*

Proof Proposition 3. *Under sharp grim trigger strategies, consumers' expectations about future prices in period* t *are:*

$$\begin{aligned} p_{t+1}^N &= p^m \text{ and } p_{t+1}^U = \alpha\theta_l \text{ if } p_t^N = p^m \\ p_{t+1}^N &= p_{t+1}^P \text{ and } p_{t+1}^U = 0 \text{ if } p_t^N \neq p^m \end{aligned}$$

Therefore, profit in the defection period is strictly less than the monopoly profit in the industry and collusion is sustained if and only if

$$\Pi_t^D \leq \frac{\Pi^m}{G\left(1-\delta_f\right)} \Rightarrow \delta_f \geq \delta_f^* = 1 - \frac{1}{\gamma^* G}$$

where $\gamma^* \equiv \dfrac{\Pi_t^D}{\Pi^m} = \dfrac{(1-\alpha)\theta_h + \alpha\theta_l - c}{(1-\alpha)\theta_h + \alpha(1+\delta)\theta_l - c} < 1$*. Observe that* $\dfrac{\partial\gamma^*}{\partial\alpha} = -\dfrac{\alpha\theta_l(\theta_h - c)}{((1-\alpha)\theta_h + \alpha(1+\delta)\theta_l - c)^2} < 0$, $\dfrac{\partial\gamma^*}{\partial\delta} = -\dfrac{\alpha\theta_l((1-\alpha)\theta_h + \alpha\theta_l - c)}{((1-\alpha)\theta_h + \alpha(1+\delta)\theta_l - c)^2} < 0$, $\dfrac{\partial\gamma^*}{\partial\theta_h} = \dfrac{(1-\alpha)\alpha\delta\theta_l}{((1-\alpha)\theta_h + \alpha(1+\delta)\theta_l - c)^2} > 0$ *and* $\dfrac{\partial\gamma^*}{\partial\theta_l} = -\dfrac{((1-\alpha)\theta_l - c)\alpha\delta}{((1-\alpha)\theta_h + \alpha(1+\delta)\theta_l - c)^2} < 0$.

Proof Lemma 3. *If the steady-state price of new goods is equal to* p^N*, consumers can choose either to buy the new good and keep it for two periods or to buy the new good every period and scrap the used one. The continuation values are* $V_1 = \frac{(1+\alpha\delta)\theta_h - c}{1-\delta^2}$ *and* $V_2 = \frac{\theta_h - c}{1-\delta}$ *respectively. The first strategy is better than the second one if* $p^N > (1-\alpha)\theta_h$*.*

Proof Proposition 4. *When the monopolist maximizes his profit by charging* $p^m = (1+\alpha\delta)\theta_h$*, the profit is* $((1+\alpha\delta)\theta_h - c)n_h/2$*. By comparing the profit with and without second hand, it easy to verify that the profit without a second-hand market is higher if* $c > (1-\alpha)\theta_h + \alpha(1+\delta)(2\theta_l - \theta_h)$ *which is always greater than* $\theta_h(1-2\alpha-\alpha\delta)$*. Hence the proposition follows.*

Proof Proposition 5. *By lemma 3 if the price of new goods in equilibrium is equal to* $p^N = c > (1-\alpha)\theta_h$*, consumers prefer buying the new good and keeping it for two periods. Consider three cases:*

- *If* $c > (1-\alpha)\theta_h$*, the highest profit is achieved by setting* $p^m = (1+\delta)\theta_h$*. Suppose firms follow the standard grim trigger strategy and charge a price equal to c from t+1 onward. The maximum price* p_t^D *that a defector can charge must leave consumers without the good indifferent between buying the good in* t *(and then keep it) and buying it tomorrow at a lower price. Then:* $\theta_h - p_t^D + \alpha\delta\theta_h + \delta^2 V_1 = \delta((1+\alpha\delta)\theta_h - c) + \delta^3 V_1$*, where*

$V_1 = \frac{(1+\alpha\delta)\theta_h - c}{1-\delta^2}$,*which implies* $p_t^D = \frac{(1+\alpha\delta)\theta_h + \delta c}{1+\delta}$. *The lower the price charged after a defection, the higher is the punishment inflicted on the defector. The lowest price the defector charges in t for any* harsher *strategy implemented is* $p_t^D = \theta_h$. *At this price the defector sells the good only to consumers without it. However he may have an incentive to further lower the price of new goods and sell to all consumers. The price should make the consumers with a used good indifferent between buying a new good in t (and buying it again in* $t+1$*) or keeping the used one, i.e.* $p_t^D = (1-\alpha)\theta_h$. *The profit in the first scenario is higher if* $c > (1-2\alpha)\theta_h$ *(which is always true if* $\alpha \geq 1/2$*) and in particular is true in the case we are analyzing. The smallest* γ *without second-hand market is* $\gamma^{without} = \frac{\theta_h - c}{(1+\alpha\delta)\theta_h - c}$. *However,* $\gamma^* = \frac{(1-\alpha)\theta_h + \alpha\theta_l - c}{(1-\alpha)\theta_h + \alpha(1+\delta)\theta_l - c} < \gamma^{without}$ *and therefore the first part of the proposition is proven. Notice that* $\gamma^* = \gamma^{without}$ *if* $c = (1-\alpha)\theta_h$.

- *If* $(1-2\alpha)\theta_h < c \leq (1-\alpha)\theta_h$ *then consumers with a used good will always buy a new good and scrap the used one for any* $p_{t+1}^N \leq c$. *Hence the maximum price that a defector can charge in the defection period is* $p_t^D = \theta_h$. *The defector does not have an incentive to further lower the price to sell to all consumers (see previous discussion). It follows that* $\gamma^* > \gamma^{without}$.

- *If* $c \leq (1-2\alpha)\theta_h$, *consider two cases:*

  - *If* $(1-2\alpha-\alpha\delta)\theta_h < c \leq (1-2\alpha)\theta_h$, *the maximum price that a defector can charge in the defection period is* $p_t^D = \theta_h$, *but he has the incentive to further lower the price of new goods and sell to all consumers with high valuation (including those with a used good). It follows that* $\gamma^{without} = \frac{2((1-\alpha)\theta_h - c)}{(1+\alpha\delta)\theta_h - c} > \gamma^*$.
  - *If* $c \leq (1-2\alpha-\alpha\delta)\theta_h$ *firms maximize their profit by selling the good to all consumers with high valuation in every period at price* $p^m = (1-\alpha)\theta_h$. *In such situation there is no longer any intertemporal link in the demand and so no extra punishment can be inflicted on the defector in the defection period, i.e.* $\gamma^{without} = 1 > \gamma^*$.

Proof Corollary 1. *If there is no trade the monopoly price is* $p^m = \theta_h$. *Firms sell the units to all consumers in every period; consumers scrap the used goods. There is no intertemporal link in demand and* $\gamma^{without} = 1$. *If there is trade, consumers in country E can sell their good to consumers in country I at price* $p^U = \alpha\theta_l \; \forall t$. *Hence firms charge a higher price* $p^m = \theta_h + \delta\alpha\theta_l$ *(I assume that if there is free trade firms prefer to sell only to the high types). There is no substitution effect in this particular case because consumers in country E will derive no utility from having a used good. At price* $p^m = \theta_h + \delta\alpha\theta_l$, *total profit is higher, firms sell the same quantity at a higher price and are able to punish the defection in the defector period because of the presence of the resale value component.*

Proof Proposition 6. *There are two relevant cases:*

- *The monopolist leases both new and used goods. The maximum leasing fee that the monopolist can charge for a used good that makes low-valuation types indifferent as to whether or not they rent a used unit is* $l_t^U = \alpha\theta_l$. *Consequently the leasing fee for a new product can be at most* $l_t^N = (1-\alpha)\theta_h + \alpha\theta_l$. *Overall, the monopolist's profit is higher than selling:*

$$((1-\alpha)\theta_h + \alpha\theta_l - c)n_h + \alpha\theta_l n_h > ((1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c)\,n_h$$

- *The monopolist chooses not to rent used goods and charge* $l_t^N = \theta_h$. *The latter strategy is better than the former if* $(\theta_h - c)\,n_h > ((1-\alpha)\theta_h + \alpha\theta_l - c + \alpha\theta_l)\,n_h \Leftrightarrow \theta_h \geq 2\theta_l$[24]. *In this case no used goods are available for low-types of consumer. The condition implies again that the monopoly profit under leasing is strictly higher than selling.*

Proof Proposition 7. *Each firm prefers collusive behavior if*

$$\mathit{\Pi}\left(l^N, l^U\right) \leq \frac{\Pi\left(l^N, l^U\right)}{G\,(1-\delta_f)} \Rightarrow \delta_f^l \geq 1 - \frac{1}{G}$$

The condition is equal to the usual condition that we have in the standard repeated game model where $\gamma^l = 1$.

Proof Proposition 8. *In order to affect the secondary market the monopolist has to commit to and offer a buy-back price* b^U $\forall t$ *at least equal to* $\alpha\theta_l$. *No consumers will sell a used good to a firm below this threshold and the policy is not binding.*

The maximum price for new goods that a high-taste consumer is willing to pay is given by the following equation:

$$\theta_h - p_t^N + \delta b^U = \max\{\alpha\theta_h - b^U, 0\}$$

There are two relevant ranges of values for b. If the monopolist commits to $b^U \in [\alpha\theta_l, \alpha\theta_h]$, *then in each period the monopoly price is* $p^N = (1-\alpha)\,\theta_h + \delta b^U$ *and his profit is* $\left(p^N - c\right) n_h$ *minus the cost of carrying out the policy,* $b \cdot n_h$ *(the cost of buying back the used goods available on the market). The profit function is strictly increasing in* b^U: $\frac{\partial\left(p^N - c\right)n_h - b^U \cdot n_h}{\partial b^U} = \delta > 0$. *Hence in this range the optimal buy-back price is* $b^U = \alpha\theta_h$.

If $b^U > \alpha\theta_h$,*the monopoly price is* $p^N = (1-\alpha)\,\theta_h + \delta b^U$ *and the cost of the policy is still* $b^U \cdot n_h$, *now that the profit is strictly decreasing in* b^U. *This implies that the optimal strategy for the monopolist is* $b^* = \alpha\theta_h$ *and* $p^* = (1+\alpha\delta)\,\theta_h$. *In each period, high-taste consumers will sell used goods to the monopoly and buy new goods. It follows that the*

[24] I am implicitly assuming that the monopolist never finds it optimal to sell to all consumers.

monopoly profit is $((1+\alpha\delta)\,\theta_h - c)\,n_h - \alpha\theta_h n_h$. *The monopoly profit is higher than selling if* $((1-\alpha+\alpha\delta)\,\theta_h - c)\,n_h \geq ((1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c)\,n_h \Leftrightarrow \theta_h \geq \frac{1+\delta}{\delta}\theta_l$. *To prove the last part we need to consider two cases: (i) if* $\theta_h < \frac{1+\delta}{\delta}\theta_l$ *then the statement follows from proposition 6 (ii) if* $\theta_h \geq \frac{1+\delta}{\delta}\theta_l$ then we have $(\theta_h - c)\,n_h > ((1-\alpha+\alpha\delta)\,\theta_h - c)\,n_h$.

Proof Proposition 9. *With buy-back we can define* $\gamma^{bb} = \dfrac{(1-\alpha)\,\theta_h - c}{(1-\alpha+a\delta)\,\theta_h - c}$, *whereas* $\gamma^* = \dfrac{(1-\alpha)\,\theta_h + \alpha\theta_l - c}{(1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c}$. *It is straightforward to observe that* $\gamma^{bb} < \gamma^*$ *or* $\theta_l((1-\alpha)\,\theta_h - c) < \theta_h((1-\alpha)\,\theta_h - c)$. *Hence the minimum discount factor that sustains the monopoly outcome with buy-back is always lower than* δ_f^*.

Proof Proposition 10. *The monopolist will offer a warranty when it increases the consumers' willingness to pay and hence the price:* $p^m = (1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l \; < (1-\omega)\,\theta_h + \omega\,(1+\delta)\,\theta_l = p^w$ *or* $\omega\,(\theta_l\,(1+\delta) - \theta_h)\,(1-\varphi) > 0$ *and if the benefit is greater than the expected costs:* $\omega\,(\theta_l\,(1+\delta) - \theta_h)\,(1-\varphi) > k\varphi$.

Proof Proposition 11. *Define* $\gamma^\omega = \dfrac{(1-\omega)\,\theta_h + \omega\theta_l - c - k\varphi}{(1-\omega)\,\theta_h + \omega\,(1+\delta)\,\theta_l - c - k\varphi}$ *and* $\gamma^* = \dfrac{(1-\alpha)\,\theta_h + \alpha\theta_l - c}{(1-\alpha)\,\theta_h + \alpha\,(1+\delta)\,\theta_l - c}$. *It follows that* $\gamma^\omega - \gamma^* = -\dfrac{\omega\delta\theta_l\,((\theta_h - c)\,(1-\varphi) + k\varphi^2)}{(p^\omega - c)\,(p^* - c)} < 0$, *so that the minimum discount factor that sustains the monopoly equilibrium outcome is strictly lower with the warranty.*

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