

## **Taxation and Durable-Goods Monopoly: Does a Current Tax Influence Firm Behavior?**

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**Abstract:** A simple two-period linear demand durable-goods monopoly model is analyzed where the firm faces an ad-valorem tax. Unlike previous models, the impact of an expected future tax is not analyzed; rather it is assumed the tax only is levied in the first (current) period. The model shows that such a current tax can dramatically impact the monopolist's behavior. For example, the analysis reveals that, as long as the product is durable, the firm wishes to concurrently rent and sell in period one if it faces a current ad-valorem tax. This indicates that the current tax policy on durables, separate from any expected future tax, likely also has a strong impact in imperfectly competitive durable-goods markets.

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### **1. Introduction**

There is a long-standing literature that has explored the behavior of durable-goods producers in imperfectly competitive markets. This research primarily focuses on the dynamic consistency of the firm's optimal output and pricing strategy (given that any durable units of the good sold in an earlier period still survive for use in future periods). This implies the firm is effectively in competition with its own stock of sold units in future periods.

In a seminal article, Coase (1972), argued that since buyers hold the existing stock of the durable-goods in future periods (not the firm), they will rationally expect the selling firm to decrease the future price at the buyers' expense. Put differently, as the future price is decreased, any loss in the value of these durable units is borne by buyers and *not the firm*. This suggests that a durable-goods seller has no interest in incorporating these capital losses in any future output and pricing decisions it makes. Coase argued that there will be a constraint placed on the firm's behavior due to these rational expectations of buyers. Specifically, Coase conjectured that a selling monopolist will be forced to price the durable goods closer to its marginal production cost due to this expectation constraint.

This so-called "Coase conjecture" has been subsequently shown to hold by a variety of authors in many different settings.<sup>1</sup> These authors, amongst many others, show unless the firm can credibly satisfy its current buyers it will not decrease the future price of the durable-goods to their detriment, the time-consistency of the firm's optimal strategy is impacted. Waldman (2003) provides an

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<sup>1</sup> See, for example, Stokey (1981), Bulow (1982, 1986), Butz (1990), Goering (1992), Olsen (1992), Morita and Waldman, (2004), Arya and Mittendorf, (2006), Kinokuni, Ohkawa, and Okamura (2010), and Wolitzky, (2010)).

excellent survey of the durable-goods literature and the Coase conjecture in general. In short, studies have confirmed that unless the seller can credibly commit to buyers in some fashion, buyers' rational expectations will indeed constrain a durable-goods seller and it will tend to earn less profit than a pure renter (i.e., the seller's behavior is altered). In terms of the seller's behavior, these durable-goods models typically focus either on the monopolist's choice of product durability (i.e. "product obsolescence") or its choice of rentals versus sales. Renting or leasing, obviously, avoids any commitment problem with buyers completely. Hence, in the rental case there typically is no reason for product obsolescence (inefficiently short-lived output) and if the firm is given the choice of rental or sales it will tend to rent all units.

Recently, the implication of tax policy on the behavior of an imperfectly competitive durable-goods producer has raised interest. In particular, Goering and Boyce (1996), Driskill and Horowitz (2007), Kim, Kim, and Chun (2009), and Chen, Esteban, and Shum (2010), all analyze the impact of various tax schemes on a seller's commitment problem with their potential buyers. They all find that an expected future tax helps credibly commit a durable-goods seller to a lower future output (higher future price). This tends to mitigate the firm's commitment problem with current buyers; therefore, these expected future taxes are less detrimental to the firm's profit than non-durable goods firms. However, all of these extant studies focus on the impact of expected *future* taxes on a monopolistic seller's behavior.

In this paper, we show that *current* tax policy, in terms of an ad-valorem tax, can also have profound impact on a seller's dynamically consistent behavior. Ad-valorem taxation on durables is, of course, extremely common in virtually all economies. These taxes are seen in many different forms, e.g., sales taxes, property taxes and value added taxes (VAT) on durables. Many countries also impose a duty or tax on imported durable-goods such as automobiles. Thus, we present a stylized two-period durable-goods model with an ad-valorem tax in the first-period, and show that even when there is no future tax, the monopolist's behavior is significantly impacted. We proxy the durable-goods monopolists behavior by its rental-sales choice (Although similar results could be obtained with durability choice as the proxy instead).<sup>2</sup> We show that the firm wishes to concurrently rent and sell units in period one if it faces an ad-valorem tax only in this period.<sup>3</sup> This indicates that the current taxation on durable-goods, distinct from any expected future tax policy, likely has an important impact on monopolistic durable-goods markets.

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<sup>2</sup> Note, for example, a number of states in the USA (e.g., Illinois, Texas and New York) require that the sales tax due on automobile leases must be paid *entirely* up front. This tax is levied on either the full sales price of the automobile or the sum of entire stream of rental/lease payments. In other words, regardless of whether an automobile is leased or sold, the ad-valorem (sales) tax is only levied in the current period (and no future periods).

<sup>3</sup> In an unpublished working paper Kim, Kim, and Chun (2009) analyze the impact of a property tax (levied in all periods) on the durable-goods monopolist's renting/selling behavior. However, these authors focus on a solution where the firm only produces a *perfectly* durable-goods in the *first* period and never again, i.e., on a so-called corner solution. Moreover, as do all the other existing durable-goods tax analyses, they do not analyze the impact of a *current* ad-valorem tax on firm behavior, but rather focus on the commitment aspects of the *future* property tax. Hence, their analysis, although complementary to ours, is very different.

## 2. A Basic Durable-Goods Monopoly Model Given a Current Ad-Valorem Tax

As in Bulow (1982, 1986), we suppose a monopolist produces a durable-goods over a two-period horizon. To analyze the impact of current tax policy on the firm's behavior, we will explore the firm's choice of its rental/sales ratio.<sup>4</sup> To this end we let  $\alpha \in [0,1]$  represent the fraction or percentage of period one production that is rented or leased (as opposed to sold). Hence, if the firm chooses to rent all period one durable units it will set  $\alpha = 1$ , conversely if it sells all these units it would set  $\alpha = 0$ . Since we are proxying the firm's behavior by its rental sales choice  $\alpha$ , we *exogenously* specify product durability as  $\delta \in [0,1]$ .<sup>5</sup> The parameter  $\delta$  is simply the percentage or fraction of first period output that is still available for use in the second period (i.e., still in circulation). Hence, if the firm's period one output is perfectly durable then  $\delta = 1$ , and if  $\delta = 0$ , its output is non-durable (no period one units will survive for use in period two).

In terms of the market demand for durable-goods, we assume a simple linear service demand in each period that depends upon the stock of the durable-goods in circulation. If we let  $q_1 > 0$  and  $q_2 > 0$  represent the firm's output levels in period one and two respectively, then these service demands are:<sup>6</sup>

$$p_1 = a - bq_1 \quad \text{and} \quad p_2 = a - b(\delta q_1 + q_2) \quad (1)$$

In (1), we see that the demand for service of the durable (i.e., the rental price in each period) is linearly related to the available stock of output in the period. The stock in period one is simply the firm's period one output  $q_1$ . However, in period two it consists of second period production  $q_2$ , plus any remaining serviceable units from period one  $\delta q_1$ .

In terms of the connection between sales and rentals, we suppose (as is standard) if the firm sells a unit of the good with durability  $\delta$ , it simply receives the discounted stream of the expected rental prices depending. If we let  $\beta \in [0, 1]$  represent the discount factor, we can thus write the period one sales price as (2).

$$p_1^s = p_1 + \beta \delta p_2 = a - bq_1 + \beta \delta [a - b(\delta q_1 + q_2)] \quad (2)$$

As expected, if the good is non-durable so  $\delta = 0$ , from these equations (1) and (2) we see there is, in fact, no distinction between selling and renting a period one unit of output. Indeed, there is no difference in the second period between selling and renting a unit of output since there is no future period for durability to provide any benefit. Thus, in our simple two-period framework, selling and renting are equivalent in period two regardless of the good's period one built-in durability  $\delta$  and (as is standard) is simply suppressed.

On the cost side, as in Bulow (1982), we specify a simple cost structure where the firm faces constant marginal manufacturing costs in period one and two  $c_1 > 0$  and  $c_2 > 0$  respectively. Thus,

<sup>4</sup> In terms of the rental versus sales issue some representative studies are: Bucovetsky and Chilton (1986), Bhatt (1989), Purohit (1995), and Goering and Pippenger (2009).

<sup>5</sup> As noted in the introductory section I, alternatively we could utilize product durability as a proxy to explore the impact of a current (period one) tax on the monopolist's behavior with similar results.

<sup>6</sup> Note that we are focusing on interior solutions here where the firm produces output in both periods (since most real world manufacturers of durables produce in every period due to the high costs of "mothballing" plants).

although we are assuming constant marginal costs in both periods, these costs are allowed to vary between periods.<sup>7</sup>

The final element we need before formulating the monopolist's profit function is, of course, the form of the ad-valorem tax that will be levied in the first (current) period. As noted in the introduction section, ad-valorem taxation on durable-goods is very common and is seen in many different guises, such as sales taxes, property taxes, duty on imports, and value added taxes. We do not seek to model fully the intricacies of ad-valorem taxation in general, but rather suppose that a tax rate of  $\tau_1 \geq 0$  is imposed on the firm's revenue stream in the current period. Specifically, we assume that the firm, regardless of whether it sells or rents first period units, must pay  $\tau_1$  on the *full value* of the units produced in period one. For example, some states in the USA (e.g., Illinois, Texas and New York) require that the sales tax due on automobile leases must be paid entirely up front. The tax may be levied on the full sales price of the automobile or the sum of entire stream of rental/lease payments. In other words, notwithstanding whether an automobile is rented or sold,  $\tau_1$  must be fully paid in the current period. Hence, as a proxy for the wide-class of ad-valorem taxes in use, we assume that the current ad-valorem tax  $\tau_1$  is simply based on the sales price (stream of service prices) given in (2), and that it must be paid in the first period irrespective of the firm's choice of rental versus sales of the durable unit. We further suppose that no future (period two) tax will be levied. This allows us to focus entirely on the impact of the current ad-valorem tax  $\tau_1$  on the firm's rental-sales choice  $\alpha \in [0,1]$  in the next analysis section.

Before, moving to the analysis section III we introduce the firm's discounted profit function, using (1), (2), our cost and tax assumptions:

$$\begin{aligned} \pi = & [(1 - \tau_1)(p_1 + \beta\delta p_2) - c_1]q_1 + \beta(p_2 - c_2)q_2 = \\ & [(1 - \tau_1)(a - bq_1 + \beta\delta(a - b(\delta q_1 + q_2)) - c_1]q_1 + \beta(p_2 - c_2)q_2 \end{aligned} \quad (3)$$

The profit function in (3) is the standard discounted stream of service (rental) prices of the good, with durability  $\delta$  and ad-valorem tax  $\tau_1$ , less manufacturing costs. Note the tax  $\tau_1$  is levied on the entire stream or value of the durable-goods  $(1 - \tau_1)(p_1 + \beta\delta p_2)$  in the current period one, notwithstanding the rental sales choice  $\alpha$ .

This immediately begs the question: what does the rental-sales choice  $\alpha \in [0,1]$  impact since it does not appear in (3)? To understand this note, that while the monopolist always seeks to maximize (3), it can only do so unconstrained if is not subject to the rational expectations of economic agents involved in the durable-goods market. We know if the firm sells any period one durable unit (sets  $\alpha < 1$ ) then, as noted earlier in the introductory section I, the firm faces the Coase conjecture.

Hence, the firm faces a commitment problem with rational period one buyers and, in effect, must maximize (3) subject to the buyers' expectations when it sells units where  $\alpha < 1$ . Period one buyers know the firm will re-maximize in the second period since the surviving period one units sold  $(1 - \alpha)\delta q_1$  are owned by buyers and *not* the firm. In other words, we seek the dynamically consistent path for the monopolist.

Note when the firm exclusively rents ( $\alpha = 1$ ), all the remaining durable units from period one are still owned by the firm in period two. In traditional durable-goods monopoly models it is assumed that this implies the firm simply maximizes the discounted portion of (3) with respect to  $q_2$ , which rearranged, implies equation (4):

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<sup>7</sup> We could specify a more general cost function, as in Bulow (1986), but the impact of current tax policy on the monopolist's behavior are qualitatively similar so we utilize the simpler assumption.

$$\begin{aligned} \max_{q_2} \pi_2^r &= (\delta q_1 + q_2)p_2 - c_2 q_2 - \delta q_1 \tau_1 p_2 = \\ &(\delta q_1 + q_2)[a - b(\delta q_1 + q_2)] - c_2 q_2 - \delta q_1 \tau_1 [a - b(\delta q_1 + q_2)] \end{aligned} \quad (4)$$

sans the discount factor  $\beta$ . Thus, it is typically argued that the unconstrained maximization of discounted profits in (3) will be dynamically consistent (sub-game perfect) in the pure rental case since the firm still owns all period one units. As soon as the firm sells any period one unit  $\alpha < 1$ , however, it faces a different objective function and problem in the second period, namely:

$$\max_{q_2} \pi_2^s = (\alpha \delta q_1 + q_2)[a - b(\delta q_1 + q_2)] - c_2 q_2 \quad (5)$$

Equation (5) indicates that the monopolist has no incentive to include the previously sold units in its re-maximization in period two (choice of  $q_2$ ) since it no longer *owns* these  $(1 - \alpha)\delta q_1$  surviving units. Furthermore, the firm has no incentive to consider the impact of period two production on its period one tax bill since this has already been paid. Hence, rational period one buyer will expect the firm to solve (5) instead of (4) in period two, since all period one decisions are “water under the bridge” at this point. Hence, the dynamically consistent solution is found by maximizing (3) subject to the solution of (5) for all  $\alpha < 1$ .

This raises the interesting question: is the firm constrained at all when it rents *all* period one units, i.e., when  $\alpha = 1$ ? In other words, will the pure renting firm maximize (4) instead of (5) (with  $\alpha = 1$ ) when it reaches period two? We argue that this is *not* in fact dynamically consistent here, in contrast to the standard durable-goods case, and that the firm must solve (5) with  $\alpha = 1$  and not (4).

If the firm rents all its period one units it can be argued it is not subject to buyers’ rational expectations. However, we know that once the firm moves to the second period it will still wish to maximize (5) since the tax burden for period one is “water under the bridge” (i.e., ignore the term:  $-\delta q_1 \tau_1 p_2$ ). In other words, even a pure renter can only maximize (3) if it *can commit* itself in period one to its entire time path (period two production) and *cannot* re-maximize in period two. The other economic agent in this durable-goods market here is, of course, the government who receives the tax revenue in period one. It will not rationally expect the renting firm to solve (4) when it reaches period two (nor would multi-period renting consumers). Rather, it will expect the firm to simply maximize its periodic profit in (5) since the firm is no longer concerned with the previous period’s ad-valorem tax  $\tau_1$ . Hence, the dynamically consistent solution here is still governed by (5) and not (4) even for a *pure renter*. This is in stark contrast to the standard durable-goods model’s assumption that a pure renter has no incentive to deviate in future periods from its announced path since it owns all units.

Note that the renter’s commitment problem is diametrically opposed to the seller’s commitment problem. A seller wishes to commit to produce less in the future to maintain a high market value of units previously purchased (Coase conjecture). A renter facing a current ad-valorem tax wishes to commit to more production in the future (and less today) to lessen the tax burden. Once it reaches the future (second period), it no longer has any desire to fulfill this commitment. Instead, it will wish to decrease its announced period two production to a lower pure monopoly level.<sup>8</sup> This gives our first proposition.

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<sup>8</sup> As in the sales case, a variety of commitment mechanisms exist here to solve the renter’s commitment problem. In particular, analogous to sales contracts (e.g., best buy provisions for a seller) the renter could sign a multi-year binding contract with a lessee that *cannot* be renegotiated in the future. This likely helps partially explain the use of such contracts in durable-goods rental markets such as autos.

**Proposition one:** *In a market where the sole manufacturer of a durable-goods faces a current ad-valorem tax  $\tau_1$ , a commitment problem exists even for a pure renter. This commitment problem is in addition to the well known seller's commit problem, and induces a pure renter to announce a greater future production than it wishes once the future period is reached.*

The renter here faces a commitment problem in that it wishes to commit to a *higher* second period output while a seller (ignoring the tax) wishes to commit to *lower* output in this period. We find this juxtaposition of wants, will have profound effects on the durable-goods monopolist's behavior and will induce them to concurrently rent and sell units in the first period. Our model clearly shows that a current ad-valorem tax may cause even a pure renter to wish to deviate from its announced behavior in future periods. Hence, in the next section we explore the time-consistent solution given that the firm faces a current (period one) ad-valorem tax  $\tau_1$  in the absence of any rental or sales commitment ability (contracting).

### 3. Rental versus Sales Given a Current Ad-Valorem Tax

To explore the impact of a current first period ad-valorem tax  $\tau_1$  on a durable-goods monopolist's time-consistent desire to rent or sell, we begin in period two by maximizing the firm's profit with respect to  $q_2$ . Thus, we seek the solution of (5) for any arbitrary rental fraction  $\alpha \in [0,1]$ . This maximization yields the firm's optimal second period output:

$$q_2^* = \frac{a - b(1 + \alpha)\delta q_1 - c_2}{2b} \quad (6)$$

Note that, although the rental fraction  $\alpha$  clearly impacts the firm's choice of period two production directly, the ad-valorem tax in period one  $\tau_1$  does *not*. Thus, as opposed to the earlier durable-goods tax studies (e.g., Goering and Boyce (1996), Driskill and Horowitz (2007), and Chen, Esteban, and Shum (2010)) we are *not* relying on the fact that an expected future tax credibly commits the durable-goods monopoly seller to a decreased future output (since it binds the firm to higher future costs). Our model does not rely on such a commitment mechanism of taxation for changes in the firm's behavior. Rather, we focus on the impact of the *current* tax  $\tau_1$ .

To show the impact of  $\tau_1$  we move to the first period optimization of firm profits in (3) subject to (6). This will yield the dynamically consistent (sub-game perfect) solution. Hence, we differentiate (3) with respect to period one production  $q_1$  and the rental fraction  $\alpha$ , obtaining (7) and (8).

$$q_1^* = \frac{a[2(1 - \tau_1) - \beta\delta\tau_1 - 2c_1 + c_2\beta\delta(2 - \tau_1)]}{b[4(1 - \tau_1) - \beta\delta^2\tau_1^2]} \quad (7)$$

$$\alpha^* = 1 - \tau_1 \quad (8)$$

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However, for uniformity among selling and renting, we assume in the analysis (Section 3) no such contracting in either sales or rental markets take place.

It is immediately apparent from (8), that a monopolist without any commitment ability wishes to concurrently sell and rent units in period one as long as the ad-valorem tax is greater than zero ( $\tau_1 > 0$ ).<sup>9</sup> This can be contrasted with the standard durables-goods result that the monopolists will simply rent all units to avoid the Coase conjecture (see Waldman (2003)). This illustrates that *current* taxation on durable-goods, separate from any future tax policy expectations, likely has important impacts on monopolistic durable-goods markets.

**Proposition two:** *A durable-goods monopolist facing a current ad-valorem tax  $\tau_1$ , and no future tax, will wish to simultaneously rent and sell units in the current period.*

The intuition for proposition two is that the current tax introduces a commitment problem for the renting firm. The renter wishes to announce an increased future output to help lessen its current tax burden. Once it reaches the future period, however, it has no desire to account for this “tax effect” in its profit re-maximization. The government taxing authority (as well as multi-period renters) recognizes this, and as such, a commitment problem akin to a seller’s commitment problem with potential buyers exists. However, unlike the seller’s commitment problem, the renter wishes to credibly commit to *higher* future production rather than lower future output. Thus, selling here helps credibly commit the firm to higher future output, which tends to mitigate its commitment problem with the taxing authority and increase its profit. Nonetheless, selling also increases the firm’s commitment problem with potential current buyers, which tends to decrease its profit (Coase conjecture). In our highly parameterized linear demand model, this combination of competing effects leads to the simple concurrent rentals and sales fraction shown in (8).<sup>10</sup>

It is worth noting, once again, that in contrast to previous tax studies in durable-goods markets; our result does not depend upon the commitment effect of an expected future tax. Rather, propositions one and two are due to the presence of an ad-valorem tax that is only levied in the *current* period. Hence, currently levied taxes in imperfectly competitive durable-goods markets, may have as large an impact on firm behavior as expected future taxes.

## 4. Concluding Comments

In this paper we explore the impact of ad-valorem tax in the current period on a durable-goods monopolist’s behavior, as stylized by its rental-sales choice in the first period. A simple two-period linear demand model illustrates that the firm will likely wish to simultaneously rent and sell durable units in contrast to the conventional wisdom.

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<sup>9</sup> As is standard, we assume all the parameters are such that optimal interior solutions with positive production in both periods prevail (e.g.,  $\tau_1 < 1$ ,  $c_1 < a$ ,  $c_2 < a$ ,  $a[2(1 - \tau_1) - \beta\delta\tau_1] - 2c_1 + c_2\beta\delta(2 - \tau_1) > 0$  and,  $4(1 - \tau_1) - \beta\delta^2\tau_1^2 > 0$ ).

<sup>10</sup> As expected, if there is no current tax ( $\tau_1 = 0$ ), our model confirms the conventional wisdom that a firm without any commitment ability with potential buyers will simply wish to rent all period one units ( $\alpha^* = 1$ ). In other words, if no tax/rental commitment problem exists the firm optimally rents exclusively. Also, as expected, if the good is non-durable ( $\delta = 0$ ), it is easy to show the tax does not have any impact since  $\frac{\partial\pi}{\partial\alpha} = -\frac{1}{2}\beta b q_1^2 \delta^2 (\alpha + \tau_1 - 1) = 0$ , which yields (8). Hence, it is the combination of product durability *and* the period one ad-valorem tax that drives our results.

Our analysis is interesting in that it shows that a currently levied tax may have profound effects on imperfectly competitive durable-goods markets in and of themselves. Previous studies have established the importance of future expected taxes on the firm's behavior (e.g., how they may change the firm's durability choice or rental-sales ratio). Our model indicates that ad-valorem taxation in the current period also may impact the firm's optimal choices.

We show that with a current ad-valorem tax even a pure renter may face a commitment (dynamic consistency) issue. We find that such a renter will wish to commit to more production in the future in an attempt to decrease its current tax burden. However, once the future is reached, the renter no longer has any incentive to carry through with this increased production, since the tax is now "water under the bridge." Even though renting does not provide any commitment ability, the sales of units does credibly bind the firm to increased future output. Nevertheless, selling also causes a commitment problem with potential buyers of the durable-goods (the well known Coase conjecture), so pure selling is typically not optimal. We show a mix of rental and sales may well be profit maximizing.

There are a number of avenues for future research. For example, one could take our model and analyze durability choice rather than the choice of a rental-sales ratio. Likely this extension would show that an uncommitted seller's desire for "planned obsolescence" would be less than what has been traditionally thought (e.g., see Bulow (1986)), since selling offers a credible way for the firm to avoid some of its current tax burden. Another extension would be to include a thorough specification of the characteristics of the various ad-valorem taxes in use around the world (rather than our stylized approach). These extensions, as well as others, will likely lead to new insights in durable-goods market settings.

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