Mergers in Durable-Goods Industries: A Re-examination of Market Power and Welfare Effects

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MERGERS IN DURABLE-GOODS INDUSTRIES:
A RE-EXAMINATION OF MARKET POWER AND WELFARE EFFECTS

by

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ABSTRACT

In a classic paper on the welfare effects of mergers in durable-goods industries, Carlton and Gertner (1989) argued that the presence of a competitively supplied stock of used units substantially reduces the social-welfare losses associated with mergers that increase market power. Their analysis employed an approach to modeling durable-goods markets that was popularized by Swan in the early 1970s in which new and used “service units” are perfect substitutes in consumption. We employ a modeling approach similar to those employed in recent contributions by Waldman (1996) and Hendel and Lizzeri (1999) which, more realistically, does not make this perfect substitutability assumption. Our analysis confirms the result that a competitively supplied stock of used units does typically reduce the welfare loss associated with a durable-goods merger. However, we also show that this reduction is much smaller than found in Carlton and Gertner’s analysis. The implication is that the antitrust authorities should be more concerned about mergers in durable-goods industries than the existing literature suggests.
I. INTRODUCTION

Most of the theoretical literature concerning the effects of mergers focuses on nondurable-goods industries, but in the real world many of the mergers of concern to regulatory authorities are in durable-goods industries.¹ This paper contributes to a small but important literature concerning the effects of mergers in durable-goods industries. In particular, we explore the implications of adopting a new and more realistic approach to modeling durable-goods markets that has been explored by various authors over the last ten years. We show that employing this new approach yields social-welfare losses associated with durable-goods mergers that are larger than losses found in the previous literature on this topic, which suggests the antitrust authorities should be more concerned about mergers in durable-goods industries than a reading of the previous literature on this topic might indicate.

The classic paper on the welfare effects of mergers in durable-goods markets is Carlton and Gertner (1989). Their focus is on how an existing stock of used units serves to limit the welfare loss associated with a merger that increases market power. In particular, they consider a durable-goods market initially characterized by perfect competition in which a merger results in a monopoly outcome. They also assume that after the merger the monopolist rents rather than sells its output which eliminates time inconsistency as an issue. Their main result is that, if durable units depreciate slowly, then the stock of used units that exist at the time of the merger both stops the post-merger monopolist from significantly raising the price immediately after the merger and limits the deadweight loss due to monopoly pricing in the first few periods that follow the merger. In turn, they conclude that, if depreciation is slow and competitive entry is anticipated within a few periods, then the expected aggregate social-welfare loss due to the merger may be so small as to not warrant the attention of the antitrust authorities.

Carlton and Gertner’s analysis employs the approach to modeling durable-goods markets popularized by Peter Swan in the early 1970s (see Swan (1970,1971) and Sieper and Swan (1973)).² In

¹ The economic analysis of mergers encompasses a vast and diverse literature spanning oligopoly theory, game theory, and other branches of industrial organization. Texts such as Tirole (1988), Carlton and Perloff (1999), and Vives (2000) all detail much of the foundations of modern merger analysis. Perhaps the most concise summary of widely accepted lessons from this literature is embodied in the joint DOJ/FTC Horizontal Merger Guidelines (1997). The guidelines are largely focused on the analysis of non-durable good industries. In fact, mention of durable goods is limited to two sentences related to the evaluation of the timeliness of post-merger competitive entry.

² Swan traces this approach to modeling durable-goods markets back to Wicksell (1934). Also, see Schmalensee (1979) for a survey of the literature that explores this approach to modeling durable-goods markets and Waldman (2003) for a survey that discusses this literature and more recent contributions to durable-goods theory.
this approach, each unit of the durable good can be thought of as a bundle of service units that decay over time, where a service unit derived from a used unit of output is a perfect substitute for one derived from a new unit and consumer preferences are modeled as demand for service units. Further, at any point in time, one can think of the flow demand for service units first being satisfied by the existing stock of used units, and new durable units then satisfying the residual demand. When thought of in this way, the logic for the Carlton and Gertner result is clear. If the speed of decay of durable units is slow, then the residual demand the monopolist faces in the first few periods following the merger will be small which, in turn, limits potential social welfare losses in those first few periods.

In recent papers, Waldman (1996) and Hendel and Lizzeri (1999) have criticized Swan’s approach and reanalyzed some fundamental issues concerning durable goods in models that employ a distinctly different approach. The criticism is straightforward. In a Swan-type model, a consumer can combine service units derived from a number of used units to create a perfect substitute for a new unit. Although this may be a reasonable assumption for some products, for most durable products such as televisions, refrigerators, and automobiles in which only one physical unit is used at a given time, it is not a realistic assumption. In their papers, Waldman and Hendel and Lizzeri consider models that do not satisfy this assumption but rather each individual consumes a single unit of the product or no unit at all and used-unit depreciation is modeled as a reduction in the unit’s quality. They show that employing this alternative approach overturns some basic findings in the durable-goods literature. For example, in contrast to Swan’s conclusions, they find that even in the absence of commitment problems a durable-goods monopolist does not typically choose the socially optimal level of durability.

In this paper we consider the welfare effects of durable-goods mergers employing the basic approach to durable-goods modeling explored in Waldman (1996) and Hendel and Lizzeri (1999). In addition to consumers not being able to combine used units to create a perfect substitute for a new unit and depreciation being modeled as a reduction in the unit’s quality, the other main assumptions are that

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3 A related approach is explored in Fudenberg and Tirole (1998) who assume no used-unit depreciation but rather that newer vintages are of higher quality.

4 As discussed in detail in Waldman (1996), this alternative approach to modeling durable goods is closely related to the classic analyses of Mussa and Rosen (1978) and Maskin and Riley (1984) of a monopolist who sells a product line of different qualities to consumers who vary in their valuations of quality (see also Moorthy and Png (1992)). The basic idea is that, in this approach to modeling durable goods, one can think of the monopolist as producing a product line over time in which new units are the high-quality units while the different vintages of used units are the lower qualities in the product line.
consumers are differentiated with respect to valuation for quality, new units are sold rather than rented, and there is a frictionless secondhand market on which used units trade. Following Carlton and Gertner, our analysis focuses on an industry that is initially competitive and then a merger leads to a monopoly outcome. Further, the monopoly is assumed to persist for a finite number of periods after which entry causes the market to revert back to a competitive outcome. The impact of this short-lived monopoly is then analyzed and, in particular, compared with the Carlton and Gertner findings.

Our analysis of this model yields three main results. First, price increases following the merger are both dramatic and immediate—in particular, we find price changes immediately following the merger that range between 26% and 245% of the competitive price level. Second, if entry occurs a small number of periods after the merger, then consistent with the Carlton and Gertner analysis we find that the present discounted value of welfare losses is smaller than in the analogous nondurable-good case. However, although this present discounted value is smaller than in the analogous nondurable-good case, for similar parameter values it is substantially larger than in Carlton and Gertner’s analysis. Third, increasing the number of periods till entry occurs not only increases the absolute welfare loss due to the merger, but also moves the welfare loss in the durable-goods case closer (in percentage terms) to the welfare loss in the analogous nondurable-goods case. In fact, if the number of periods is sufficiently high, the welfare loss in the durable-goods case can even exceed the loss in the analogous nondurable-goods case. In summary, we confirm Carlton and Gertner’s basic argument that in durable-goods industries the presence of a competitively supplied stock of used units will typically reduce the social-welfare loss associated with a merger that increases market power. However, we find the magnitude of this reduction to be much smaller than in Carlton and Gertner’s analysis.

The obvious question is, what causes the differences between our analysis and Carlton and Gertner’s, and the answer is the difference in assumptions discussed above concerning the ability of consumers to combine used units to create a perfect substitute for a new unit. Consider what happens after a merger in Carlton and Gertner’s analysis. Because of the frictionless secondhand market that reallocates service units to those consumers with the highest valuations, any consumer with a high valuation for the product consumes a new unit or used units that in aggregate are equivalent to a new unit, so with respect to high valuation consumers there is no reduction in social welfare. The aggregate reduction in social welfare is due solely to the existence of consumers who should consume the product but do not, where these are consumers whose valuations for the product are close to the “marginal”...
valuation in the competitive case, i.e., individuals for whom consuming the product yields a small social surplus. Now suppose depreciation is slow. Then immediately after the merger the aggregate stock of service units embodied in new and used units will be close to the pre-merger level and the number of consumers who “should” but do not consume the good will be small. The small number of affected consumers combined with the fact that the loss in social welfare per affected consumer is small means the aggregate welfare loss must be small as well.

Now consider our analysis. In any period in our model each individual consumes a single unit or no units at all, where due to the frictionless secondhand market there is a perfect positive correlation between an individual’s valuation for the product and the quality of the product consumed. Now suppose there is a merger and after the merger the resulting monopolist reduces the output of new units below the competitive level. In contrast to what was true in Carlton and Gertner’s analysis, it is not just the consumers for whom consuming the product yields a small social surplus who are affected. Rather, many individuals are affected some of whom have valuations far above the valuation of the marginal consumer in the competitive case. The reason is that, because used units cannot be combined to form a perfect substitute for a new unit, the reduction in the supply of high-quality units necessarily means that some high valuation individuals will consume lower quality units than previously. The result is that, as the monopolist reduces output, numerous individuals scattered throughout the valuation distribution wind up consuming a good of lower quality than was true in the competitive case. Hence, the loss in social welfare is larger here because more individuals are affected, some of the affected individuals have valuations for the product that far exceed that of the marginal consumer in the competitive case, and reducing the quality consumed of a high-valuation consumer significantly reduces surplus.

So the basic argument here is that a Swan-type setting is not only characterized by the unrealistic assumption that used units can be combined to form a perfect substitute for a new unit, but in addition this unrealistic assumption translates into a similarly unrealistic picture of the social-welfare consequences of a merger that significantly increases market power. Hypothetically, suppose a series of mergers among automobile manufacturers moved the industry from a competitive situation to one characterized by a monopolist. Further, suppose that in the period after this series of mergers this monopolist chose an output level equal to half the competitive output. Under the Swan assumptions, in the period after the mergers there is little or no social-welfare loss due to the consumption decisions of individuals who would have purchased new units under competition but do not under monopoly. The
reason is that most or all of these individuals combine the services of multiple used cars so that services
consumed is the same as if they had purchased new cars. But clearly this is not a correct description of
what would happen if such mergers actually occurred. From a real-world perspective and consistent with
our analysis, social welfare would fall due to the consumption decisions of these individuals because the
cars they would consume would be of lower quality than would be the case if the mergers had never
occurred.

Besides Carlton and Gertner’s analysis, there are two other papers that consider the effects of
durable-goods mergers. As do Carlton and Gertner, Froeb (1989) considers a setting characterized by
Swan-type durability and the effects of a merger that changes a competitive situation to one characterized
by a monopolist. He assumes the monopolist sells rather than rents, but avoids time inconsistency by
assuming that in its first period of operation the monopolist commits to a sequence of outputs for all
future periods. Rather than focusing on the social-welfare losses due to such a merger, Froeb’s focus is
on the speed with which the monopolist raises price by at least five percent above the competitive level
and on the monopoly steady-state price level. His main finding is that faster depreciation results in the
monopolist raising price more quickly and a higher monopoly steady-state price.

More recently Reitman (2001) challenges the robustness of Carlton and Gertner’s conclusions by
having the monopolist sell rather than rent its output as does Froeb (1989), and allowing consumers to
extend the lifetime of a unit by paying repair costs that are increasing in the age of the unit. As was true
for the other papers, he employs the Swan durability assumptions and focuses on a merger that moves a
competitive setting to a monopoly outcome. Also, he avoids time inconsistency by assuming the
monopolist irreversibly chooses a capacity level and sells that amount every period. Using numerical
examples, he shows that the initial price increase following the merger is on the order of one-third of the
final price increase and final prices are one to one and one-half times the competitive price level. The
monopolist is able to exercise market power immediately because consumers correctly anticipate even
higher prices in the future (this issue does not arise in Carlton and Gertner’s analysis because of their
assumption the monopolist rents its output) and rationally chooses to purchase new units immediately
and consume them for more periods. As with Froeb (1989), the focus here is on the speed of price
changes and eventual steady-state price levels rather than on the social-welfare losses due to the merger.

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5 As in our paper, Reitman models rational consumers with the ability to behave strategically in terms of their
scrappage and maintenance decisions, and he also assumes the monopolist can commit to an output sequence
As a final introductory point, consider the public-policy implications of our analysis. The analysis in this paper in a sense confirms but in another sense contradicts the Carlton and Gertner conclusions. Suppose depreciation is slow and merger now is likely to lead to entry relatively quickly. Then we agree with Carlton and Gertner that the antitrust authorities should be less concerned about a durable-goods merger that increases market power than they should be for an analogous nondurable-goods merger. However, we depart from Carlton and Gertner in two ways. First, because the social-welfare loss due to such a merger is reduced much less by the fact the product is durable in our analysis than theirs, our belief is that the scrutiny of the antitrust authorities should be relatively similar across the two cases (our interpretation of Carlton and Gertner is that they feel the antitrust authorities should be much less vigilant in the durable-goods case). Second, because in our analysis the reduction in the social-welfare loss due to durability depends strongly on the speed of future entry, we would emphasize more than Carlton and Gertner do the likely speed of future entry as an important determinant of whether or not durable-goods mergers should be allowed.

II. MODEL AND PRELIMINARY ANALYSIS

In this section we first present our durable-goods model. We then provide some preliminary results that focus on consumption choices, prices, and scrappage decisions. In the last subsection we then use these preliminary results to characterize competitive steady-state behavior. In the following section we consider the monopoly steady state and the transition dynamics associated with a merger that moves the market from competition to monopoly.

A) The Model

We consider an infinite-period model in which new units are initially produced by a perfectly competitive industry (or alternatively there is initially a duopoly and Bertrand price competition). At some date \( t' \) a merger or series of mergers occurs that collapses this competitive situation to a single monopoly producer, and then at some later date \( t'' \) entry occurs and the industry returns to a competitive (although different than our approach, his commitment is in terms of a one-time choice of capacity). As a consequence, there is a similarity in results in that in both papers post-merger price increases are immediate and substantial. In contrast, however, although Reitman does not analyze welfare losses of the merger, we suspect that on this dimension the results would be quite different. That is, because Reitman employs a Swan-type specification, in his model welfare losses are confined to consumers who receive little surplus from consuming the durable product and so these losses should be much smaller than what we find.
situation. Following Carlton and Gertner we assume that both the initial merger to monopoly and the subsequent entry are unanticipated by producers and consumers (we also discuss how results would change if the subsequent entry were anticipated rather than unanticipated). Our focus will be on the speed with which price increases after the merger and the social-welfare losses due to the monopolist’s output reductions.

Each manufacturer has a constant marginal cost of production equal to \( c \) and no fixed costs of production. A new unit produced by any manufacturer is of quality \( Q^N \), while a used unit of age \( s \) is of quality \( a^s Q^N \), \( 0 < a < 1 \), i.e., used-unit quality is negatively related to the age of the unit. Further, we also assume that a used unit can be scrapped at a fixed value \( z \) that is independent of the unit’s age. Note that in addition to consumers being able to purchase new units from manufacturers, there is a frictionless secondhand market on which consumers buy and sell used units. Further, in any period the prices of the various vintages of used units simply equate supply and demand.

On the demand side, we assume a continuum of consumers of total mass \( N \) who are heterogeneous in terms of their valuations for quality. In particular, each consumer \( i \) has a valuation for quality \( v_i \), where the valuations for quality in the population are distributed uniformly over the interval \([0,1]\). We thus have that individual \( i \) derives a gross benefit in period \( t \) equal to \( v_i a^s Q^N \) from consuming a unit of age \( s \), where it is assumed that in each period an individual in this world consumes either zero physical units or one physical unit of output (a new unit is thought of as being of age zero).

We also assume that consumers face a cost of maintenance that is an increasing function of the age of the unit. Specifically, the cost of maintaining a unit of age \( s \), denoted \( m(s) \), is given by \( m(s) = b_0 + b_1 s \). Note that the linear form we assume is consistent with studies of the agricultural 4-wheel drive tractor industry which serves as the basis for the numerical analysis we conduct in Section IV. Let \( p(s, t) \) be the market price of a unit of age \( s \) in period \( t \). If consumer \( i \) does not own a used unit at the beginning of period \( t \), then the consumer’s net benefit in period \( t \) for consuming a unit of age \( s \) is given by \( v_i a^s Q^N p(s, t) - m(s) \). If the consumer does own a used unit at the beginning of the period, then the sale price of the unit is added to this expression for net utility. Finally, the firm and all consumers have a discount factor \( \delta, 0 < \delta \leq 1 \).
B) Preliminary Results

This subsection provides some preliminary results concerning consumption choices, prices, and scrappage decisions. Let $S(t)$ denote the age of the oldest unit that is consumed in period $t$. Given the net benefit expression above for an individual consuming a unit of age $s$ in period $t$, we have that consumer $i$ in period $t$ prefers a unit of age $s$ to a unit of age $s'$ if equation (1) is satisfied.

$$v_i > \left[ p(s,t) - \delta p(s+1,t+1) + m(s) \right]/\alpha^Q$$

That is, consumer $i$ prefers a unit of age $s$ to a unit of age $s'$ in period $t$ when the consumer’s net benefit from consuming the age-$s$ unit plus the discounted value of its $t+1$ price is greater than the consumer’s net benefit from consuming an age-$s'$ unit plus the discounted value of its $t+1$ price. Note that this equation could have been written to include the sale price of any unit owned by the consumer at the beginning of the period, but this term would appear on both sides of the inequality and so would cancel out.

By isolating $v_i$ in equation (1) we can derive necessary and sufficient conditions for individual $i$ to consume a unit of age $s$ in period $t$. These are given by equations (2), (3), and (4).

$$v_i < \left[ p(s',t) - \delta p(s'+1,t+1) + m(s') - p(s,t) + \delta p(s+1,t+1) - m(s) \right]/\alpha^Q$$

$$v_i > \left[ p(s,t) - \delta p(s+1,t+1) + m(s) - p(s',t) + \delta p(s'+1,t+1) - m(s') \right]/\alpha^Q$$

$$v_i > \left[ p(s,t) - \delta p(s+1,t+1) - m(s) \right]/\alpha^Q$$

Equation (2) ensures that the consumer prefers a unit of age $s$ to all newer units, (3) ensures that a unit of age $s$ is preferred to all older units, while (4) ensures that the consumer prefers a unit of age $s$ to not consuming any unit at all.

We now turn to scrappage decisions, prices, and the allocation of new and used units among consumers. There are two things that are straightforward. First, given the positive scrap value, monotonically decreasing quality (utility from consumption), and the maintenance cost which is a linear increasing function of a unit’s age, units are not consumed indefinitely but are rather scrapped at some finite age. Second, in any period there is a perfect negative correlation between a consumer’s value for $v_i$ and the age of the unit the individual consumes (for this statement interpret not consuming a unit as consuming a unit that is infinitely old). This follows from our assumption of a frictionless secondhand market and the fact that higher $v_i$ consumers are willing to pay more for the incremental quality associated with consuming a newer unit.
We now turn to how prices are determined. Remember that \( S(t) \) denotes the age of the oldest unit consumed in period \( t \). Also, let \( v(s,t) \) be the valuation of the lowest-valuation individual who consumes a unit of age \( s \) in period \( t \). Consider some period \( t \). In considering consumption decisions regarding goods of age \( S(t) \) there are two cases. The first is that some units of age \( S(t) \) are scrapped while others are consumed. Given that units of age \( S(t) \) are scrapped, we have that \( p(S(t),t)=z \). We also know that the price is equal to the net benefit the marginal consumer of the unit derives from its consumption plus the discounted value of the market price of the unit in the following period, i.e.,

\[
p(S(t),t)=v(S(t),t)\alpha^{S(t)}Q^N-m(S(t))+\delta p(S(t)+1,t+1).
\]

The logic here is that, if the price were above this sum the marginal consumer would be unwilling to buy a unit of age \( S(t) \), while if it were below then a lower valuation consumer would want to purchase a unit of age \( S(t) \).

Now consider a unit of age \( S(t)-1 \). The price of this unit equals the sum of the price of a unit of age \( S(t) \), the savings in maintenance costs from consuming a unit of age \( S(t)-1 \) rather than a unit of age \( S(t) \), the amount the marginal consumer of an age-\( S(t)-1 \) unit places on the incremental quality associated with a new unit, and the discounted value of the difference in the following period’s market prices, i.e.,

\[
p(S(t)-1,t)=z+b_1+v(S(t)-1,t)(\alpha^{S(t)-1}-\alpha^{S(t)})Q^N+\delta(p(S(t),t+1)-p(S(t)+1,t+1)).
\]

In turn, we can generalize this result to derive the price for any unit of age less than \( S(t) \). This is given in equation (5).

\[
(5) \quad p(s,t)=p(s+1,t)+b_1+v(s,t)(\alpha^s-\alpha^{s+1})Q^N+\delta(p(s+1,t+1)-p(s+2,t+1)) \quad \text{for all } t \text{ and } s<S(t)
\]

Note that this price function is similar to how prices are determined in the static product line pricing literature such as Mussa and Rosen (1978) with the addition of the discounted difference in the following period’s market prices of the units (see footnote 4).

The other case is that no used units of age \( S(t) \) are scrapped rather than consumed. First, using the same logic as in the first case, we know that in this case the price of a unit of age \( S(t) \) must equal the net benefit the marginal consumer of the unit derives from its consumption plus the discounted value of the market price of the unit in the following period. Second, in contrast to the first case, since no units are scrapped this price must be greater than or equal to the scrap price rather than necessarily being equal to the scrap price. Third, as in the first case, the price of a unit whose age is strictly less than \( S(t) \) is given by equation (5).

The next result concerns the relationship between the age of the oldest unit consumed in a period, \( S(t) \), and the lowest valuation individual who consumes a unit in the period, \( v(S(t),t) \). These two variables are linked together through the basic equilibrium condition that supply must equal demand. Let
\( \gamma_t, 0 < \gamma_t \leq 1, \) be the proportion of age-\( S(t) \) units that are consumed rather than scrapped in period \( t \) and \( y_i \) be aggregate industry output in period \( t \). Then the following condition must hold.

\[
(1 - \nu(S(t), t))N = \gamma_t y_i + \sum_{j=1}^{S(t)} y_{i+1-j}
\]

The left hand side of equation (6) is the total number of consumers demanding a unit, while the right hand side is the total supply of units on the market given that \((1 - \gamma_t)\) of the age-\( S(t) \) units are scrapped.\(^6\)

Given that all units of age strictly less than \( S(t) \) are consumed in period \( t \) and there is a positive correlation between the quality of a unit and the valuation of the individual who consumes the unit, we can also derive a similar condition for each \( \nu(s, t), s < S(t) \). This is given in equation (7).

\[
(1 - \nu(s, t))N = \sum_{j=1}^{s} y_{i+1-j}
\]

The left-hand side is the total number of consumers whose valuation for quality exceeds \( \nu(s, t) \), while the right-hand side is the total supply of units age-\( s \) or newer.

We can use the above results to derive a condition that determines whether in some period \( t \) the outcome is consistent with case 1 or case 2. Let \( v_t^* \) satisfy \( v_t^* = \lceil 1 - \sum_{j=1}^{S(t) + 1} y_{i+1-j} \rceil / N \), i.e., \( v_t^* \) is the lowest valuation individual who would consume a unit in period \( t \) if in period \( t \) all units of age \( S(t) \) were consumed rather than scrapped. Period \( t \) will be consistent with case 1 if equation (8) is satisfied,

\[
v_t^* \alpha^{S(t)} Q^N - m(S(t)) + \delta p(S(t) + 1, t + 1) < z,
\]

while it will be consistent with case 2 if equation (9) is satisfied,

\[
v_t^* \alpha^{S(t)} Q^N - m(S(t)) + \delta p(S(t) + 1, t + 1) \geq z.
\]

That is, some units of age \( S(t) \) will be scrapped if in the absence of scrappage the price for such a unit would be strictly less than the scrap price, while none of these units will be scrapped if in the absence of scrappage the price for such a unit would be greater than or equal to the scrap price. Similarly, given (5), (6), and (7), \( S(t) \) and \( \gamma_t \) are characterized by equation (10).

\[
p(S(t), t) = \geq z \text{ if } \gamma_t \leq (=) 1
\]

Note, if \( \gamma_t = 1 \) and \( p(S(t), t) > z \), then \( S(t) \) is the highest value consistent with \( p(S(t), t) > z \).

\(^6\) For this statement, an individual who consumes the same unit he or she owned at the beginning of a period is thought of as selling the unit to him or herself.
C) Competitive Steady State

A steady state in this model is characterized by a constant output of new units, \( y \), a constant highest age of used units that are consumed, \( S \), a constant proportion of these used units that are consumed, \( \gamma \), a vector of constant prices, \((p_0, \ldots, p_S)\), for various vintages consumed in a period, and a vector of constant valuations, \((v_0, \ldots, v_S)\), that captures the lowest valuation consumer of each vintage consumed. Further, the price vector must satisfy equation (5) while equations (6) and (7) determine the vector of minimum valuations as a function of \( y \), \( S \), and \( \gamma \). In the competitive case, the model is closed by the fact that the zero-profit condition associated with competition means that the new-unit price, \( p_0 \), must equal the marginal or average total cost of production, \( c \).

To be more precise, the way this works in the competitive case is as follows. Let \( p_0 = c \) and choose an arbitrary (for the moment) value for \( y \). For any \((S, \gamma)\) pair, equations (6) and (7) determine the vector \((v_0, \ldots, v_S)\), while this vector in combination with equation (5) and the fact that the price vector is constant determines the price vector \((p_0, \ldots, p_S)\). The \((S, \gamma)\) pair is then the unique pair that results in \( p_S = z \) or, if no such pair exists, then \( \gamma = 1 \) and \( S \) is the highest value such that \( p_S > z \). Finally, given this, the steady-state value for \( y \) is the unique value that results in \( p_S \) equalling the sum of the net value that the marginal consumer of an age-\( S \) unit places on the unit plus the discounted value of an age-\( S+1 \) unit’s market price.

III. MONOPOLY STEADY STATE AND TRANSITION DYNAMICS

In this section we analyze both the monopoly steady-state solution to the model and the transition dynamics associated with a merger that transforms a competitive steady state to a monopoly outcome. Before presenting these two analyses, however, we begin the section by discussing our assumption concerning monopoly and commitment.

A) Durable-Goods Monopoly and Commitment

As first discussed by Coase (1972) and later formalized by Bulow (1982), in the absence of the ability to commit to future actions, a durable-goods monopolist faces a time-inconsistency problem that lowers its own profitability. The basic logic is easily seen by considering Bulow’s two-period analysis of a monopoly seller. In that analysis the monopolist’s second-period output choice affects the second-period value of units sold as new in the first period, which means the price for new units in the first
period depends on consumer expectations concerning this second-period choice. The time-inconsistency problem is that, if the monopolist cannot commit in the first period to this second-period choice, then in the second period it ignores the effect of its output choice on the second-period value of these used units and chooses an output level above what it would choose if it could commit. In turn, the anticipation of this behavior by consumers in the first period lowers both the first-period price and overall monopoly profitability. Bulow also shows that the problem can be avoided if the monopolist rents rather than sells its output.

Following Coase and Bulow’s contributions, most of the literature on durable-goods monopoly assumes commitment about future prices and quantities is not possible and thus focuses on the time-inconsistency problem concerning output choice. However, consistent with Butz (1990) who shows that contractual provisions such as best-price provisions or most-favored-customer clauses can ameliorate the problem, we feel that in most real-world settings commitment or at least partial commitment concerning output is possible and thus that the time-inconsistency problem concerning output choice is less central than the literature suggests. Think, for example, of a firm that sells commemorative coins. It sells a good that is basically perfectly durable, and it can sell the good today or at any later date. On the surface this seems to be exactly the type of firm that should be subject to time inconsistency. In reality, however, time inconsistency is not typically a significant problem in such cases because firms commit to upper bounds on future quantities through what is called a limited edition. Another way to put this is that Coase’s insights are important not because durable-goods sellers frequently fall victim to the time-inconsistency problem he identified, but rather because his insights help us understand various contractual provisions that allow firms to mostly avoid the problem.

A further justification for allowing a post-merger durable-goods monopolist to avoid the time-inconsistency problem concerning output choice was put forth by Froeb (1989). His basic point is that, since the main goal of considering durable-goods mergers is the evaluation of the potential anticompetitive harm from such a merger, it makes most sense to consider a case where time inconsistency is absent or at least of limited importance. In other words, as first pointed out by Coase, a durable-goods monopolist that falls victim to time inconsistency concerning output choice behaves in a competitive or close to competitive fashion. Hence, it is only when the monopolist can avoid time

7 See, for example, Stokey (1981), Gul, Sonnenschein and Wilson (1986), and Ausubel and Deneckere (1989).
inconsistency that the merger is even potentially an antitrust concern, so that is the case one should focus on in evaluating the potential social harm of a durable-goods merger.

Consistent with the above discussion and also with the previous papers discussed in the Introduction that focus on durable-goods mergers, we assume that after the merger the monopolist is able to solve its commitment problem concerning output choice and thus avoid the time-inconsistency issue. There are two main ways that the literature has identified for how a durable-goods monopolist can avoid the time-inconsistency problem concerning output choice. The first way is that, as discussed above, the firm can sell its output and either directly or indirectly contractually commit to future output choices, while the second is that, as first discussed by Coase and Bulow, the firm can rent as opposed to sell its output. In the analysis that follows we take the former approach and assume that immediately after the merger the post-merger monopolist commits to a sequence of future production levels.

There are three reasons for why we assume that the monopolist avoids time inconsistency by selling its output and committing through contracting rather than renting its output. The first is that this approach is analytically simpler. When the firm sells its output and avoids time inconsistency through contracting, the only choice is a new-unit production level for each period. In contrast, in the rental case the firm chooses a production level for each period plus how many used units of each vintage to retire in each period, where the return to retiring used units before the market price exceeds the scrap price is that this raises the price at which new units can be rented. As indicated, introducing this issue significantly complicates the analysis.

The second reason we assume selling and commitment rather than renting concerns moral hazard. That is, although we do not explicitly model the problem, if consumers can affect the quality of used units through their maintenance decisions then selling and commitment may be preferred over renting because of moral hazard. The idea is that a consumer who rents will underinvest in maintenance because the consumer anticipates returning the unit to the manufacturer at the end of the rental period.

8 In addition to contracting and renting, Bulow (1986) shows that a durable-goods monopolist may reduce its time-inconsistency problem by reducing the durability of its output. Ausubel and Deneckere (1989) show that reputation formation is a way for a firm to avoid the problem, while Karp and Perloff (1996) and Kutsoati and Zabojnik (2001) argue that a firm can sometimes reduce the problem by initially using an inferior high-cost technology.

9 See Waldman (1997) for a formal analysis along these lines. Also, a similar issue arises in the selling case if we were to allow the monopolist in each period to repurchase and scrap used units (see Waldman (1997) and Fudenberg and Tirole (1998)).
(see Mann (1992) for an analysis along these lines). The third reason is that there are antitrust concerns that go back to the 1953 *United Shoe Machinery Case* that limit the ability of durable-goods producers with significant market power to employ policies that result in most units being rented.

As a final related point, one might argue that our approach is unrealistic since the type of contractual commitment that we assume is not typical among durable-goods producers with significant market power. However, one interpretation of our analysis is that in the period following the merger the monopolist does not in fact commit to all future output levels, but rather after the merger the monopolist behaves as if it could commit because of the returns associated with establishing a reputation for not falling victim to the time-inconsistency problem. As Ausubel and Deneckere (1989) show, a durable-goods monopolist can sometimes partially or even fully avoid the time-inconsistency problem concerning output choice because of the incentives for reputation formation associated with repeated interaction.

**B) Monopoly Steady State and Transition Dynamics**

In the monopoly steady state, when the firm maximizes the present discounted value of profits today and in later periods it chooses the output sequence that maximizes per period profits. As described in the previous section, in any period the prices of the various vintages are functions of the total stock of new and used units available. We can use equations (5) through (10), which we will refer to as the pricing equations, to solve for the new-unit price as a function of steady-state output, $y$, and the model parameters, and then use that to derive per period profit as a function of the model parameters and in turn the optimal new-unit output. To be precise, for a given choice of new-unit output level, the first step is to determine the associated scrappage age $S$ along with the proportion of such units consumed, $\gamma$. Knowledge of the $(S, \gamma)$ pair then determines the set of pricing equations for new and used goods. Noting that the price of the age-$S$ good is set to the scrap price in each period, we can then recursively solve pairs of pricing equations for the equilibrium price of each successively younger vintage until the entire steady-state price vector is established. Given this, we can then substitute the expression for the new-unit price into the per period profit function, $\pi = y[p_0(y) - c]$, to yield per period profit as a function of new-unit output and the model parameters. Finally, given the expression for per period profit as a function of new-unit output, one can then optimize to solve for the monopoly steady state.

We now turn our attention to the transition dynamics associated with merger to monopoly. Given any arbitrary sequence of new-unit outputs, it is possible to determine for each period the age of
the oldest unit consumed and the equilibrium prices. The pricing equations tell us that the price of a unit of age \(s\) in period \(t\) is determined by its own price in period \(t+1\), the prices of age-\(s-1\) and age-\(s\) units in periods \(t\) and \(t+1\), respectively, and the total mass of used units of age \(s\) or less in period \(t\). In turn, given the price of any given vintage good must equal the scrap price, \(z\), in any period in which units of that vintage are scrapped, we can work recursively backwards from the price at the scrap date to solve for all the prices of a good over its lifetime.

To see the logic here in more detail, let us fix a sequence of new-unit outputs and focus on the sequence of prices for new units produced at some date \(t'\). Further, let \(t'+j\) be the last period in which units produced in period \(t'\) are consumed. To keep things simple, assume that \(0<\gamma_i<1\) for all \(t'\leq t\leq t'+j\) so that the price of the oldest unit consumed in each period \(t\), \(t'\leq t\leq t'+j\), equals the scrap price. This assumption also guarantees that the oldest unit consumed in each of these periods is of age \(j\), and that no units produced in period \(t'\) are scrapped prior to period \(t'+j\). We can also easily determine the period \(t'+j-1\) price of a new unit produced in period \(t'\). Since in period \(t'+j-1\) some units produced in \(t'-1\) are scrapped and some are consumed, the period \(t'+j-1\) price for such a unit is just the scrap price. Given this, equations (5) and (7) yield that the period \(t'+j-1\) price for a new unit produced in \(t'\) is given by (11).

(11) \[ p(j-1, t'+j-1) = z + b_1 + (1 - \gamma_j) y_{t+j}/N)(\alpha^{j-1} - \alpha^j)Q^N \]

In turn, this last calculation can be performed for a new unit produced in every period \(t\) and in this way solve for every period’s prices for used units of age \(j\) and \(j-1\).

Now consider period \(t'+j-2\). The price of a used unit of age \(j\) equals the scrap price, while the price of a used unit of age \(j-1\) is determined by equation (11) (after substituting \(t'+j-2\) for \(t'+j-1\)). Given this, the price in \(t'+j-2\) for a new unit produced in period \(t'\) is determined by equation (12), where in the equation the price of an age \(j-1\) unit in period \(t'+j-1\) is also determined by equation (11).

(12) \[ p(j-2, t'+j-2) = p(j-1, t'+j-2) + b_1 + (1 - \gamma_{j-1}) y_{t+j-1}/N)(\alpha^{j-2} - \alpha^{j-1})Q^N + \delta_p(j-1, t'+j-1) - z \]

For a new unit produced in any period \(t\), continually repeating this procedure allows us to solve for all the prices during the lifetime of the unit including the period-\(t'\) price. In turn, given prices for new units produced in every period \(t\), we can calculate the present discounted value of profits for any sequence of new-unit outputs.

Given we now have a way of computing profits for any sequence of new-unit outputs, the remaining issue is how to search for the optimal or profit-maximizing sequence over all possible
sequences of outputs. There are a few important issues concerning this search. First, if each period’s value for S(t) were known beforehand, then it might be possible to apply dynamic programming methods to derive a function that gives the monopolist’s choice of output in each period as a function of the stock of used units available at the time of the merger. However, because any period’s value for S(t) is determined by the actual stock of units available for consumption in that period, dynamic programming approaches will not work since the structure of the problem is not known until a sequence of new-unit outputs has actually been specified.

Second, even though the monopolist is solving an infinite-period problem, we are only interested in the first few periods following the merger. To make the search for an optimal sequence of new-unit outputs feasible, we treat the infinite-period problem as a finite-period problem by assuming that from period T>>0 onwards the monopolist’s output is fixed at the monopoly steady-state level. Whether convergence to the steady state would have occurred by time T is immaterial for our analysis as long as T is sufficiently far in the future that outputs after period T have little influence on the firm’s decisions at the beginning of the output sequence. In the analysis below, we set T=151. In other words, the monopolist’s problem is to choose an output sequence for the first 150 periods following the merger such that the present discounted value of profits is maximized given the assumption that output is equal to the monopoly steady-state level starting in period T=151.10

The problem was programmed using MATLAB, and a constrained numerical gradient line search optimization routine was used to solve for the optimal sequence of outputs from t=1 to T-1(=150). In this routine numerical gradients are calculated that are then employed to determine search direction and step size during each iteration. The specific search routine employed is consistent with the BFGS method which is a standard approach for doing numerical optimization searches. Note that, in general, numerical optimization searches of this sort do not inherently guarantee convergence to a global optimum. To increase confidence in the obtained solution, for each parameterization we considered several different vectors of starting values. In all cases the solution obtained was independent of the starting values chosen.11

10 For a number of the parameterizations we explore, we have considered values for T above 151 and there were no noticeable changes in the results.

11 For further discussion see MATLAB documentation for the function “fmincon” and Appendix B of Judge et al. (1985).
IV. A NUMERICAL EXAMPLE

For the purposes of examining and illustrating the properties of our model, this section presents an analysis of a numerical example based on the market for large 4-wheel-drive agricultural tractors. This market has been the focus of several previous analyses of mergers in durable-goods markets characterized by active secondhand markets. We first parameterize the model described in the previous section making reference to this real-world market and then investigate our hypothetical merger scenario. Employing this approach allows us to analyze the welfare effects due to a merger in our framework and compare the results to previous analyses that employ a Swan-type durability assumption. Before proceeding, however, we emphasize again that the analysis in this section is meant to illustrate the properties of our model as opposed to being an effort to describe and predict actual outcomes in the tractor market.

A) Parameterization and Steady-State Results

New 4-wheel-drive agricultural tractors are currently priced between $100k and $150k. Assuming that the current situation is close to a competitive equilibrium, prices should be close to both a seller’s average total cost and marginal cost for the quality of tractor sold. We thus assume for our analysis that each seller’s constant marginal cost of production equals $100k. The parameters for the linear repair cost function are from Perry and Nixon (1991) who employ an equation in the Agricultural Engineers Yearbook (1986), where the equation gives annual tractor repair costs as a function of the new-unit price and cumulative hours of use. Employing a new-unit price of $100k (which is the competitive price in our model given a marginal cost of $100k) and assuming a constant annual hours of usage (common across all consumers) of 800 hours per year, our repair cost function is given by \( m(s) = -768 + 1536s \).\(^{12}\) Note that this repair cost equation was parameterized using 1989 data, so it might somewhat underestimate current repair costs. This, however, should not affect the qualitative nature of the results.

For the other parameters of the model, real-world evidence concerning the 4-wheel-drive tractor industry provides less guidance. With this in mind, we allow the rate of quality deterioration, \( \alpha \), to vary and in particular we consider values between .5 and .95. Similarly, we allow the quality of a new unit,\(^{12}\) Perry and Nixon (1991) use the repair cost equation in an analysis of optimal tractor replacement ages. In their analysis they assume 400, 800, and 1200 annual hours of usage.
$Q^N$, to vary between 100k and 200k. Finally, the remaining parameter which is the scrap price, $z$, is set equal to $100$ (one percent of the new unit marginal cost) which, given a slow rate of depreciation and our assumptions for the other parameters, yields plausible values for the retirement age in the competitive steady state.

We now turn to steady-state results. Table 1 compares the competitive and monopoly steady states for different values of the model parameters. Not surprisingly, the table shows that the age of the oldest unit consumed is increasing in the rate of quality depreciation. This simply says that used units will be retired later when there is an increase in the vector of qualities corresponding to used units of various ages. Another straightforward result is that the age of the oldest unit consumed is at least as high under monopoly as under competition. From earlier analyses, we know that the net valuation of the marginal consumer of the oldest unit consumed equals the scrap value $z$. As the monopolist restricts output, the valuations of the consumers of units of any fixed age must rise. Since a consumer’s net valuation for consuming a unit of fixed quality is positively related to the consumer’s valuation for quality, as the consumer valuations associated with any fixed vintage rise the age of the oldest unit consumed must (weakly) increase for the net valuation of the marginal consumer of the oldest unit consumed to be equal to the scrap value.

Another interesting set of results in Table 1 concerns how new-unit quality affects new-unit output and the age of the oldest unit consumed. Consider first the competitive case. In that case, if we hold the depreciation rate fixed, an increase in new-unit quality increases steady-state output but generally decreases the age of the oldest unit consumed. The logic here is that in the competitive case the new-unit price is fixed, so it is not surprising that an increase in new-unit quality increases the steady-state number of new units consumed. In turn, for a fixed used-unit age, an increase in new-unit output decreases the valuations of the consumers of used units of that age. The result is that, since the valuations of the consumers of any fixed aged unit decreases, the age of the oldest unit consumed falls in order for the net valuation of the marginal consumer of the oldest unit consumed to equal the scrap value.

Now consider the monopoly case. In contrast to the competitive case, if we hold the depreciation rate fixed, in the monopoly case an increase in new-unit quality has an ambiguous effect on steady-state output (sometimes it rises and sometimes it falls) while the age of the oldest unit consumed tends to rise. The logic here is as follows. If new-unit quality rises, the monopolist typically increases its price so the overall effect on steady-state output is ambiguous. In turn, we now have that, in contrast to the
competitive case, there is no systematic change in the valuations of the consumers of units of any fixed age. Rather, what is important is that, as new-unit quality rises, there is a corresponding increase in the vector of used-unit qualities. Hence, because of this, we now have that the age of the oldest unit consumed must rise for the net valuation of the marginal consumer of the oldest unit consumed to equal the scrap price.\footnote{Given the above discussion, we can now more completely understand the competitive case. In that case there are actually two countervailing effects. First, as indicated, an increase in new-unit quality causes new-unit output to rise and thus the valuations of the consumers of units of any fixed age to decrease. Second, holding used-unit age fixed, as in the monopoly case an increase in new-unit quality causes used-unit quality to increase. The first effect suggests the age of the oldest unit consumed should fall, while the second suggests it should rise. The table indicates that for our parameterizations the first effect typically dominates.}

Table 2 presents the per period total surplus for both the competitive and monopoly steady states for various values of new-unit quality and the depreciation rate. It also presents what we refer to as the percentage deadweight loss due to monopoly which is the difference between the competitive and monopoly steady state per period total surplus values divided by the competitive value for this number. As the table indicates, the percentage deadweight losses due to monopoly are substantial varying in our simulations between 22\% and 34\%. One might also ask what are the factors that cause this percentage to be either higher or lower. But a close look at the table indicates there is not a simple answer to this question. In some cases increasing the depreciation rate increases the percentage deadweight loss, while in other cases there is a decrease. Similarly, increasing new-unit quality sometimes increases but other times decreases the percentage deadweight loss.\footnote{As shown in Gerstle (2003), the percentage deadweight loss due to monopoly is a function of the maximum age of a used unit consumed in the monopoly steady state. What happens as, for example, new-unit quality increases, is that there are discrete positive jumps in this maximum age. When new-unit quality increases but there is no change in this maximum age, then monopoly output increases and the percentage deadweight loss falls. However, when there is a positive jump, monopoly output falls and there is a corresponding increase in the percentage deadweight loss. This nonmonotonic relationship is why there is no simple pattern to the percentage deadweight loss values in Table 2.}

B) Preliminary Discussion of the Post-Merger Dynamic Adjustment

We first describe output and price dynamics given a merger that results in monopoly followed by no subsequent entry. For each of our parameterizations, there is a large drop in output in the very first period following the merger. The output sequence for each parameterization then entails a decaying cyclical fluctuation that converges to the monopoly steady-state output. Although the dynamic
adjustment path is characterized by fluctuating output, new-unit prices follow a relatively monotonic convergence path to the steady-state values. In particular, the new-unit price jumps immediately after the establishment of the monopoly, where among the parameterizations we consider the smallest price increase is 26% and the largest is 245%. The new-unit price then increases monotonically until it approaches the steady-state value at which point the price path is characterized by dampening fluctuations around the steady-state value. In his 1989 analysis, Froeb emphasizes the time it takes after a merger for the monopolist to increase the new-unit price by at least 5% as an important statistic for the evaluation of competitive harm due to the merger. Clearly that threshold is exceeded immediately in all of our parameterizations.

The primary goal of this paper is to evaluate the welfare effects of mergers in durable-goods industries. When evaluating the welfare effects of mergers, regulators in the U.S. typically assume that the supranormal profits associated with a merger that substantially increases market power will attract entry after some finite number of periods and that this entry will eliminate some or all of the market power created by the merger. With this in mind, we now assume that some fixed number of periods after the merger, entry occurs and returns the industry to a competitive situation. In order to facilitate comparison with results in Carlton and Gertner (1989), we begin by assuming that this entry is unanticipated. At the end of the analysis we consider how results change when the entry is anticipated.

In evaluating the welfare effects of a merger followed by entry a few periods later, there is one significant difference to keep in mind between the setting considered here and that considered by Carlton and Gertner. Suppose, for example, that entry occurs five periods after the merger. In Carlton and Gertner’s analysis, the social welfare-harm of the merger is limited to the five periods in which the monopoly is in existence. The reason is that, since producers have a constant marginal cost of production and Carlton and Gertner employ a Swan-type durability assumption, as soon as entry occurs both the price for a service unit and consumption levels immediately revert to their competitive steady-state values. Hence, a merger that results in a short-lived monopoly causes social-welfare losses in the periods in which the monopoly is in existence, but there are no losses once entry occurs.

Now consider what happens in our model when a merger is followed by entry five periods later. In our model the welfare losses are not confined to the five periods of monopoly. As opposed to the

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15 See Gerstle (2003) for a detailed depiction of the price and output adjustment paths.
Carlton and Gertner analysis, in this model consumption decisions are not solely a function of the new-unit price but also depend on the quantities and ages of used units available at the beginning of a period. To be precise, holding fixed the price for a new unit at its competitive steady-state value, decreasing the numbers of used units of various ages below their steady-state levels will cause some, maybe many, individuals to consume units of lower quality than is the case in the competitive steady state. Hence, when the monopolist decreases new-unit output it not only decreases welfare in the periods in which the output decreases take place, but also decreases welfare later because of the effects on the subsequent stocks of used units available for consumption.

As a final preliminary point, the analysis that follows focuses on a comparison of welfare losses from merger in our durable-goods model with the welfare losses from the same merger scenario in a nondurable-goods setting. For each parameterization, we calculate what we refer to as the deadweight-loss ratio (DWL ratio). In this calculation the numerator is the sum of discounted within period deadweight losses beginning with the first post-merger period and extending through reconvergence to the competitive steady state. The denominator is the sum of discounted within period deadweight losses from monopoly in a nondurable-goods setting. The sum in the denominator is taken over the periods between the merger and subsequent entry since for a nondurable good the market reverts immediately to the competitive steady state upon entry.

In calculating our deadweight-loss ratios, the obvious question is what is the best choice of a nondurable-goods model to serve as our nondurable-good analogue. Our approach is to use our model under the assumption that the depreciation factor, \( \alpha \), equals zero, i.e., the good fully depreciates after a single period. This is equivalent to assuming a nondurable product characterized by a linear downward sloping demand curve in each period and a constant marginal cost of production. We calibrate this demand curve so that for each parameterization the total surplus in the competitive steady state of our nondurable-good analogue is equal to the total surplus in the competitive steady state of our durable-goods model. Given our nondurable-good analogue is characterized by a linear downward sloping demand curve and a constant marginal cost of production, the per period deadweight loss due to monopoly in this nondurable analogue equals 25% of the total surplus under perfect competition.
C) A Comparison of Deadweight Loss Ratios

We begin by considering parameterizations for which entry takes place relatively quickly after the merger, i.e., five periods after the merger. These are the parameterizations for which deadweight losses due to merger are smallest and thus the ones that pose the strongest case for the position that durable-goods mergers create little social-welfare harm. Later we consider how results change when the number of periods after which entry occurs is allowed to vary. Table 3 reports deadweight-loss ratios for these parameterizations, and for comparison also provides deadweight loss ratios for the same parameterizations for the Carlton and Gertner model. Before discussing the results, there are two things to note about the Carlton and Gertner values. First, in contrast to our model, in the Carlton and Gertner model the deadweight-loss ratio is independent of new-unit quality. Second, whereas in our model the depreciation rate refers to the speed of quality decay, in the Carlton and Gertner model the depreciation rate refers to the speed of physical decay of service units under Swan-type durability.

There are two main findings captured in Table 3. The first is that varying the depreciation rate has similar qualitative effects on the deadweight-loss ratios in our analysis and Carlton and Gertner’s. In each case, as the depreciation rate rises, the deadweight-loss ratio rises, i.e., the deadweight loss due to the merger in the durable-goods case moves closer to the deadweight loss in the nondurable-good analogue. Further, in both cases the basic logic behind the result is the same. As the depreciation rate rises, the inherited stock of used units at the time of the merger becomes smaller or less significant (fewer service units in the Carlton and Gertner model and used units of lower quality in our model). In turn, this means that with faster depreciation the monopolist is less constrained in terms of exercising its market power with the result being that deadweight losses due to monopoly behavior rise.

The second main finding captured in Table 3 which is the main result of the paper is that deadweight-loss ratios are consistently higher in our model than in Carlton and Gertner’s, where for many of the parameterizations the difference is striking. For example, if we focus on slow rates of depreciation, i.e., \( \alpha \) equals .9 and .95, the deadweight-loss ratio in our analysis varies between 3.3 and 6.7 times the deadweight-loss ratio in the Carlton and Gertner analysis. For faster depreciation, i.e., \( \alpha \) equals .

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16 These values are taken from Carlton and Gertner (1989, pp. S204-S208). Note that Carlton and Gertner calculate deadweight loss-ratios given entry occurs both five and one hundred periods after the merger. Also, although Carlton and Gertner use a monopoly renter of nondurable services as their nondurable analogue in their calculation of deadweight-loss ratios, their calculations would be unchanged by assuming the same nondurable-good analogue that we employ.
.5 and .8, the deadweight-loss ratios in our analysis are proportionately closer to the deadweight loss ratios in their analysis, but to a great extent this is because with faster depreciation the deadweight loss ratios in their analysis are higher and this bounds how many times higher our ratio can be than theirs (this assumes the deadweight loss ratio never exceeds one or never exceeds one by very much). Or to put this another way, for the parameterizations in which the Carlton and Gertner analysis most strongly suggests that durable-goods mergers create small social-welfare losses, i.e., fast entry and slow depreciation, our analysis shows deadweight losses due to merger significantly higher than in their analysis.

As discussed briefly in the Introduction, this difference in deadweight-loss ratios is due to the different ways that durability is modeled across the two analyses. Carlton and Gertner assume Swan-type durability which means that a good is essentially a bundle of service units and multiple used units can be combined to create a perfect substitute for a new unit. As a result, when a merger occurs and the monopolist reduces output, higher-valuation individuals continue to purchase new units or combine used units to form a perfect substitute for a new unit. Hence, the only individuals whose consumptions levels are affected by the merger are those who received little surplus from consumption in the competitive steady state in the first place, which in turn means that at least initially there is little social-welfare loss due to the monopolist exercising its market power after the merger.

We illustrate this argument in Figure 1. Consider the parameterization in which the depreciation rate equals .95 and new-unit quality equals 200k. Figure 1 shows the deadweight loss in the first post-merger period given this parameterization of the Carlton and Gertner model and the assumption the monopolist produces zero output. As pictured, even if the monopolist produces zero the social-welfare loss is quite small. The reason is that, given depreciation is slow, the aggregate number of service units contained in the existing stock of used units is close to the steady-state level. Hence, consistent with the above discussion, any consumer who receives significant surplus in the competitive steady state is unaffected in terms of consumption by the monopolist producing zero and so the aggregate social-welfare loss must be small.

Now consider our model. In our model an individual can only consume one physical unit at a time which means that a number of used units cannot be combined to create a perfect substitute for a new unit. The implication of this assumption is that, after a merger occurs and the resulting monopolist reduces its output, it is not just the consumers who receive little surplus in the competitive steady state whose consumption levels are affected. Rather, many consumers including those who receive substantial
levels of surplus in the competitive steady state wind up consuming lower quality units than under competition. The end result is that the deadweight losses due to merger and monopoly in our analysis are substantially larger than in the Carlton and Gertner analysis.

We illustrate this argument in Figure 2. As before, consider the parameterization in which the depreciation rate equals .95 and new-unit quality equals 200k. Figure 2 shows the deadweight loss in the first post-merger period given this parameterization of our model and the assumption the monopolist produces zero output. In contrast to what was true in Figure 1, we see in Figure 2 that the social-welfare loss is substantial, where the logic for this result follows from the above discussion. Even with slow depreciation, when the monopolist produces zero all the consumers are forced to consume lower quality units than is the case in the competitive steady state. In turn, since some of these consumers receive significant surplus in the competitive steady state, the reduction in quality across the board has a significant effect on social welfare.

In Table 3 we considered deadweight-loss ratios given entry occurs five periods after the merger. In Table 4 we extend the analysis by allowing the number of periods between merger and entry to vary. There are three main results captured by the table. First, consistent with what was found in Table 3, as the depreciation rate falls the deadweight loss rises. As before, this simply captures the idea that, as depreciation slows, the existing stock of used units at the time of the merger serves as less of a constraint on the monopolist’s exercise of market power. Second, also consistent with what was found in Table 3, for most parameterizations the deadweight loss ratio is higher for our model than for Carlton and Gertner’s and this difference is substantial whenever the deadweight loss ratio for the Carlton and Gertner model is small (below, for example, forty percent). Also as before, this difference is driven by the different ways that durability is modeled across the two analyses.

The third and final result captured in Table 4 is that, holding the depreciation rate and the value for new-unit quality fixed, the deadweight-loss ratio rises with the number of periods between merger and subsequent entry. For example, given a depreciation rate of .95 and new-unit quality equal to 150k, the deadweight-loss ratio equals 16%, 36%, 50%, and 81% when the number of periods between merger and entry is five, ten, fifteen, and one hundred, respectively. Also of interest is that, as the number of periods grows large, the deadweight-loss ratio sometimes exceeds 100%, i.e., the deadweight loss for our durable-goods model sometimes exceeds the deadweight loss for the nondurable-goods analogue. The basic logic for these findings is that, as we move forward in time away from the merger, the stock of used
units at the time of the merger serves less and less as a constraint on the monopolist’s exercise of market power. This means the deadweight loss associated with the merger is higher in later periods, which, in turn, means that the deadweight-loss ratio rises with the number of periods between merger and entry.

Our final exercise is to consider how results change when entry is anticipated rather than unanticipated. Following Carlton and Gertner’s analysis, in our earlier results we assumed that the entry was unanticipated, i.e., at the time of the merger and up through the period prior to entry both the monopolist and all the consumers assumed that there would be no subsequent entry and that the monopoly would stay in place indefinitely. In Table 5 we focus on parameterizations in which entry occurs five periods after the merger and investigate how results change when entry is anticipated, i.e., at the time of the merger it is understood by both the monopolist and all the consumers that entry resulting in competition will occur five periods after the merger.  

Table 5 clearly tells us that allowing entry to be anticipated increases the deadweight-loss ratio, i.e., the social-welfare losses due to durable-goods mergers are larger and closer to losses in our nondurable-goods analogue when entry is anticipated. Further, these increases are frequently substantial, but not always so. For example, given a depreciation rate of .95 and new-unit quality equal to 100k, the deadweight loss ratio with anticipated entry is more than double the deadweight loss ratio with unanticipated entry - 32.0% versus 13.7%. On the other hand, the increase is small - 17.8% versus 16.4% - when the depreciation rate equals .95 and new-unit quality equals 150k.

The basic logic for the above finding is that when consumers anticipate entry they react in a way that aggravates the social-welfare losses due to the merger. The consumers know that when entry occurs the price for a new unit will fall to the competitive level. As a result, in the periods leading up to the entry consumers reduce their purchases of new units because they realize they can significantly lower the price they have to pay by delaying their purchases. In turn, this reduction in new-unit purchases lowers social welfare in two ways. First, it lowers social welfare in the periods leading up to the entry because

---

17 Although in Table 5 we focus on parameterizations in which entry occurs five periods after the merger, we have also considered parameterizations in which entry occurs later and qualitatively the results are the same.

18 In the nondurable-goods analogue, assuming entry is anticipated rather than unanticipated has no effect on behavior and thus no effect on the social-welfare losses due to merger. Hence, the larger values in Table 5 in the anticipated case are due solely to increased social-welfare losses in our durable-goods model. It is also of interest to note that in the Carlton and Gertner analysis, because after the merger the monopolist rents rather than sells and because the firm has a zero marginal cost of production, allowing entry to be anticipated has no effect on the results.
the reduced consumption of new units means many individuals consume lower quality units than they do under unanticipated entry. Second, it lowers social welfare in the periods just following the entry because those periods are characterized by smaller stocks of used units and this also causes many individuals to consume lower quality units than they do under unanticipated entry.

V. CONCLUSION

Consider a durable-goods merger that transforms a competitive situation to one characterized by significant market power. Immediately after the merger the presence of the competitively supplied stock of used units limits the post-merger producers from exercising their market power. In a classic paper, Carlton and Gertner (1989) explored this argument in a setting where a durable-goods merger transforms a competitive situation into one characterized by monopoly, with entry transforming the industry back to a competitive outcome relatively quickly after the merger. Carlton and Gertner show that, if the durable product depreciates relatively slowly, then the constraints posed by the existing stock of used units severely limits both the post-merger exercise of market power and the social-welfare losses due to the merger. Specifically, assuming entry occurs five periods after the merger, they find social-welfare losses due to a durable-goods merger to be less than 10% of the welfare losses due to an analogous nondurable-goods merger.

In this paper we have investigated the robustness of Carlton and Gertner’s findings to a different specification for how durability is modeled. Their analysis employed an approach to modeling durable-goods markets that was popularized by Swan in the early 1970s. In this approach new and used “service units” are perfect substitutes in consumption or, in other words, a consumer is indifferent between a new unit and some number of used units that provide the same number of service units. Recent papers by Waldman (1996) and Hendel and Lizzeri (1999) have criticized this approach as being unrealistic and investigated an alternative approach in which in each period an individual consumes either zero or one physical unit and durability captures the speed with which the quality of a unit deteriorates.

In this paper we have explored the social-welfare consequences of durable-goods mergers in a setting consistent with this more recent literature. Our first main result is that Carlton and Gertner are correct that an existing competitive stock of used units will typically result in a reduction in the social-welfare losses due to a merger that significantly increases market power. However, we also find that this reduction is much smaller when durability is more realistically modeled as speed of quality deterioration.
rather than speed of decay of service units. For example, assuming entry after five periods and
depreciation rates of .95 and .9, Carlton and Gertner in their analysis of the 4-wheel drive agricultural
tractor industry find that a durable-goods merger that transforms the industry from competition to
monopoly results in social-welfare losses equal to 2% and 8%, respectively, of the analogous nondurable-
goods merger. In contrast, focusing on the estimates based on an intermediate value for the value of a
new unit, our similar analysis yields social-welfare losses in the durable-goods case equal to 16% and
33% of the analogous nondurable-goods merger.

Our other main results concern factors that affect the difference between the social-welfare
losses in the durable-goods and nondurable-goods cases. First, not surprisingly and consistent with
Carlton and Gertner’s analysis, we find that the durable-goods social-welfare loss due to merger gets
closer to the analogous nondurable-goods social-welfare loss as the number of periods before entry
occurs grows. What is different in our analysis, however, is that as the number of periods grows large
the durable-goods loss sometimes even exceeds the analogous nondurable-goods loss, where this occurs
because output reductions in our durable-goods model affects consumers across the valuation spectrum
as opposed to merely affecting low-valuation types as in the nondurable-goods analogue. Second, in our
main analysis we focus on unanticipated entry in order to facilitate comparison with the Carlton and
Gertner analysis which also focuses on this case. We find, however, that similar to what was true when
we increased the number of periods until entry occurs, allowing entry to be anticipated rather than
unanticipated causes the durable-goods social-welfare loss to increase and thus get closer to the
analogous nondurable-goods social-welfare loss.

We believe the ramifications of our analysis are clear. Consistent with Carlton and Gertner’s
analysis, if depreciation is slow and entry is likely to be relatively quick, then the antitrust authorities
need to be less concerned about the anticompetitive effects of mergers in durable-goods industries than
they are for analogous nondurable-goods industries. We depart from Carlton and Gertner, however, in
terms of the extent of this reduced scrutiny. Whereas their analysis suggests a much reduced level of
scrutiny for durable-goods industries, our analysis suggests that the degree of latitude afforded mergers in
these industries needs to be carefully evaluated on a case-by-case basis as the bounds on welfare harm
are not nearly as constraining as a reading of Carlton and Gertner might indicate.

There are a number of directions in which the analysis in this paper could be extended, where
there are two that we feel are of particular interest. First, it would be interesting to look at different pre-
and post-merger market structures. Following previous literature on the consequences of durable-goods mergers, we assumed an industry that was competitive prior to the merger and monopolistic after the merger (and again competitive after the subsequent entry). But clearly in many if not most real-world settings both pre- and post-merger market structures are likely to be oligopolistic, where a merger increases market power but rarely results in monopoly. It would thus be of interest to extend our analysis to oligopolistic interaction both before and after the merger. Second, again following previous literature, in this paper we explored the consequences of a merger in a durable-goods industry in order to gain insight about optimal antitrust enforcement for such industries. We do not, however, directly consider the social-welfare implications of different levels of antitrust enforcement. We thus feel that it would be interesting to endogenize the entry process which would make it possible to directly investigate optimal antitrust enforcement.
### Tables and Figures

#### Table 1. Comparison of competitive and monopoly steady states

<table>
<thead>
<tr>
<th>Rate of quality depreciation</th>
<th>$Q^N$ (000s)</th>
<th>Competitive</th>
<th>Monopoly</th>
<th>Ratio of Monopoly to Competitive output</th>
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<td>New unit output</td>
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Discount rate = 0.95.
Table 2. Total surplus comparisons

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<th>Rate of quality depreciation</th>
<th>Q^N ('000s)</th>
<th>Competitive steady state</th>
<th>Monopoly steady state</th>
<th>% Deadweight Loss</th>
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Discount rate = 0.95.
Table 3. Deadweight Loss Ratios -- entry takes 5 periods

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<th>DWL ratio (CG model)</th>
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Discount factor = 0.95
Table 4. Comparative statics – time until entry

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Discount factor = 0.95
Table 5. Deadweight loss ratios, anticipated vs. unanticipated entry, entry takes 5 periods

<table>
<thead>
<tr>
<th>Depreciation rate</th>
<th>QN ('000s)</th>
<th>Unanticipated</th>
<th>Anticipated</th>
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</tr>
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<td>88.0%</td>
<td>104.8%</td>
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</table>

Discount factor = 0.95
Figure 1. Social welfare loss with Swan-type durability (flow welfare loss from elimination of new unit availability)

Service units are redistributed to the highest valuation consumers. Social welfare loss is associated with the lowest valuation individuals who no longer consume the good.

Figure 2. Social welfare loss with quality depreciation: flow welfare loss from elimination of new unit availability

Shaded areas represent within period social welfare loss. Inability to combine used units or otherwise reallocate utility across units results in welfare losses distributed across the entire range of consumer valuations.
REFERENCES

*Econometrica*, 57, 511-531.


