Optimal Durability vs. Planned Obsolescence in the Textbook Market

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Abstract

We revisit the idea that textbook publishers revise frequently in order to "kill off" the market for used books. While this view has been around for quite some time, there is an influential strand of literature in durable goods theory that challenges this idea. Recent empirical findings show that publishers are more likely to revise when the market share of used books increases. We show that the theories of the textbook market based on optimal durability are inconsistent with these findings. We then show how the alternative models of time inconsistency and quality distortion can better match these empirical findings. We also discuss how the recent innovations in the textbook market, such as leasing and durability reductions, relate to each of the three models.

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1 Introduction

Recent empirical work in the textbook market has challenged the long-standing idea that publishers revise frequently to eliminate competition with used books (see Chevalier and Goolsbee 2009). While the textbook market has long been a poster child for planned obsolescence, this new evidence illustrates the need to better empirically distinguish between the relevant models of durability in this market. Therefore the aim of this paper is to provide such an analysis and generate predictions specific to the textbook market.

Durability choice is a classic topic in the literature on durable goods, (ex. Swan 1970, 1971, 1972, Miller 1974, and Benjamin and Kormendi 1974). The question on whether producers of durable goods have an incentive to limit the usefulness of used products has been debated for over forty years. The reasoning behind planned obsolescence in this market is thus; Even though textbooks may not physically deteriorate, a revision adversely affects the value of used books. The publisher therefore has the ability to affect the value of the used textbook through the revision decision.

Some economists believe the idea of planned obsolescence to be somewhat naive.¹ Peter Swan states, “Clearly it is not the existence of a secondhand market per se which need imply any restraint on the profitability or the pricing decision of a publisher...the pure publisher selling such a durable item as an automobile is paid an amount which reflects the net present value of the stream of automobile services to possibly a whole host of future owners. Competitive secondhand auto dealers (or scrap merchants in the case of aluminum) can then buy and sell the item indefinitely without in any way restricting the power of the publisher as the original seller.” (Swan 1980) His main contention rests on the assumption that the resale value of the good is contained in the price of the new good. In this case, anything that harms the value of the good in the future will also harm the new purchase price. Under various assumptions he finds that the publisher will always chose durability to minimize production costs.

Other models of durability relax some of Swan’s assumptions and find different results. There is a strand of literature that assumes that firms are unable to commit to future actions. Under these assumptions Swan’s optimal durability result does not hold. The effect of future actions on current

¹The term ‘planned obsolescence’ relates to producers limiting durability in some way. This may be through undue product updating, under investing in durability, or excessive product innovation.
profitability are not internalized when the firm makes the decisions in the future (see Waldman 1993, 1996a; Choi 1994; and Nahm 2004).

Another strand of literature examines how new and used product quality differences can affect the durability decision. They show that the presence of low quality used goods can adversely affect the profitability of selling the higher quality goods. In these models, the producer has an incentive to reduce the value of the low quality used goods in order to make higher profits (see Waldman 1996b, 1997; and Hendel and Lizzeri 1999).

When looking for evidence of planned obsolescence, the textbook market is ideal for a number of reasons. First, as mentioned above, many industry insiders state that planned obsolescence exists in this market. Second, although there are many producers in the textbook market, once individual instructors decide on which book to use, the textbook publisher has monopoly power on that group of students. Third, textbooks are primarily sold between academic terms. Therefore a periodic model is ideal as it is more tractable and realistic. Fourth, students are often required to use the version of the text that the instructor prescribes. Old editions are rendered nearly valueless when a new edition is printed. Updating and publishing only the new edition effectively ‘kills off’ the used book market.

In this paper, we build a two period model of the textbook market that nests the three main frameworks of durability choice. In all models, the publisher makes its revision decision based on the proportion of used books that remain in the market in the later periods.

The proportion of used books in the market is determined as follows. After students use the book initially, there is a probability that they will want to keep the book as a reference. We assume that they value only the specific book that they used in the previous period. The books that are kept by students do not enter the textbook market in the next period.

The destruction of the used book market is not the only reason why publishers update textbooks. The value of textbooks whether used or new depends on if the material is up to date. Textbooks may be edited periodically in order to stay relevant. Our model allows for such considerations.

The proportion of students that keep their book depends on the state of the world. If the book is regarded as a standard reference book, more students will decide to keep their book. If the book does not earn this status, there will be more used books in the market. After the publisher sees the book’s status, it has the option of revising the textbook in the second period. Revising the book
improves the quality of the book while reducing the sale price of all old books to zero. There is a fixed cost incurred by the publisher to update to a new edition. We examine how the state of the world (and consequently the number of used textbooks in the market) affects the revision decision. We compare these results to empirical evidence from textbook markets.

We examine the model under different variants that allow for optimal durability, quality differences, as well as time inconsistency. Under conditions satisfying optimal durability, the model suggests that the number of used books in the market will prolong the revision decision. However with time inconsistency, the number of used books makes revision more likely. Under full commit and quality differences the stock of used books can have either effect on revision depending on parameters.

A recent empirical study has shown that a large market share of used books speeds up the revision process (see Iizuka 2007). In relation to this finding, this paper argues that the optimal durability assumptions are not the correct variants of this model. The firm has an incentive to publish a new edition in order to 'kill off' the market for used books. Another empirical study (Bond and Iizuka 2005) show that the stock of used books increases the sale price of new books. In our framework this only happens when firms can fully commit to future actions and used and new books are imperfect substitutes. Therefore we suggest that quality differences best describes the textbook market.

At the end of the paper, we look a the role that leasing can play in reducing the revision incentive. We show that even without the problem of time consistency, the firm may want to use leasing as a tool to reduce used books in the market.

The remainder of the paper is as follows. In section 2 we provide a literature review. In Section 3 we set up the model. In sections 4, 5, and 6 we analyze the model under the three different variations. Section 7 will be the conclusion.

2 Literature Review.

While textbooks seem an ideal place to look for evidence of planned obsolescence only recently have empirical economists examined this market (see Bond and Iizuka 2005, and Iizuka 2007, Chevalier and Goolsbee 2009). Chevalier and Goolsby (2009) use a data set of all textbooks for certain fields
sold in bookstores for a period of 10 semesters. They find that consumers are forward looking with low short run discount rates and have rational expectations. They argue that this indicates that the Swan results hold and publishers have no incentive to kill off the secondary market. However other models also assume forward looking consumers yet predict planned obsolescence. Since Chevalier and Goolsbee do not test the differences between these models they cannot conclude which of these models is the best description of real world textbook markets..

In another empirical paper, Iizuka (2007) uses data on the market for college economics textbooks to examine the revision decision. He used semi-annual textbook-level data for the years 1996-2000. Using a reduced-form discrete time duration model with time-varying covariates he analyses revision timing. He includes a number of market and book characteristics as well as a variable that captures the competition between old and new units. He finds that publishers revise more frequently when the share of used textbooks increases. He attributes this to planned obsolescence. Publishers will be more likely to "kill-off" the market for used books when the stock of used books is higher. He also finds that time since last revision also makes revision more likely. He argues this finding is likely caused by other factors such as improvements in book quality.

In a related paper with Bond, Iizuka (2005) uses the same data to look at the relationship between the share of used books and new sale price. They find that the used books in the market increases the new book price. They also present a model of the textbook pricing and production decision. There model used new/used quality differences and consumer tastes and generates results consistent to their empirical findings. There model closely resembles the quality difference variation of our model. Although there paper does not endogenize textbook revision or durability choice as ours does.

Economists have often mentioned textbooks when discussing durable goods more generally. However, little theoretical work has been done to capture the unique features of the textbook market. Because this market has a number of unique features any attempt to draw implications from previous theoretical work is difficult.

The discussion about textbook revision has largely revolved around three different types of durability models. These models predict optimal durability, time inconsistency, or quality distortions. We now briefly talk about each of these models in turn.

\[2\] With the exception of the early attempts by Miller (1974).
In a series of papers beginning in the early seventies Swan (1970 and 1980) argued that producers of durable goods choose durability efficiently. The price of a new good contains the discounted resale price of the good when it is sold secondhand. Consumers anticipate this in their decision to buy the new good. Therefore producers choose durability to minimize the cost of providing the service given by such units.

Swan’s results rely on a number of key assumptions that may or may not be reasonable when considering various markets. As these assumptions are relaxed we find theoretical evidence that planned obsolescence may in fact exist.

One key assumption in the Swan framework is the ability of a firm to commit to future actions. Consumers’ willingness to pay for the durable good in earlier periods will depend on what they expect the value of such goods to be in the future. Actions that are optimal for the firm in later periods may lower the value of the goods in earlier periods. This can hurt the firm’s overall profitability. Time inconsistency relating to output quantity has been examined in some detail (see Coase 1972, and Bulow 1982). Bulow (1986) shows how reducing durability from early periods can partially mitigate this problem.

More recently, the time inconsistency in product revision has been examined as well (see Waldman 1993, 1996a; Choi 1994; and Nahm 2004). For goods characterized by network externalities, Waldman (1993) shows that without commitment, a firm’s incentive to update the products is too high from the standpoints of both overall firm profitability and social welfare.

Similarly Choi (1994) shows that time inconsistency leads to less backward compatibility than is socially optimal or if commitment were possible. Other papers show that time inconsistency can induce excessive R&D expenditures (see Waldman 1996a; and Nahm 2004).

Another, important assumption of the Swan argument is the perfect substitutability between new and used products. Under this assumption, every consumer is indifferent between a certain quantity of the used goods and a unit of the new good. In the case of textbooks, students typically only value using a single book of that title. Therefore for Swan’s assumption to hold in the textbook setting a single new book and a single used book must be perfect substitutes.

Mussa and Rosen (1978) provide early insights on pricing a product line for non durables.

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3See Schmalensee (1979) for a broad review of the assumptions and criticisms of Swan’s argument.

4For example suppose the market price of a new text book was double the price of the used book. Under this assumption, a consumer is indifferent between using one new book or two used books.
In particular, they look at a market where consumers have heterogeneous preferences for quality. They find that the publisher will inefficiently reduce the quality of the goods sold to all consumers except those with the highest taste for quality. By so doing, the publisher can increase the profits made on the other consumers. Recently economists have extended these insights when modeling markets for durable goods (see Anderson and Ginsburg 1994, Waldman 1996b, 1997; and Hendel and Lizzeri 1999). Anderson and Ginsburg (1994) show that the secondary market may or may not be beneficial to the durable goods monopolist. A monopolist can use the secondary market to achieve quasi second degree price discrimination. Analogous to the non durables case, Waldman (1996b) suggests that the presence of the used goods limits the high value consumers’ willingness to pay for the new good. Therefore the firm has an incentive to reduce the quality of the used good. They do this through an under investment in durability. In a later paper Waldman (1997) argues that leasing policies allow the firm to profitably control the secondary market. Hendel and Lizzeri (1999) show that firms have an incentive to distort investments in durability as well as restrict consumers’ ability to maintain the goods. They show that a monopolist will never want to eliminate the secondary market altogether. But they can improve profits by directly controlling the secondary market through leasing.

Other papers that discuss heterogeneous quality preferences consider different frictions. For example, Lee and Lee (1998) examine price discrimination based on purchase history.

This is the first paper to synthesize the three main types of durability models into a single framework to discuss the textbook market. By so doing, we can make testable predictions that are explicit to the specific nature of this market.

3 The Model

Consider a publisher selling textbooks for two subsequent periods. All agents are perfectly patient over this period. Each period a continuum of nonatomic buyers enters the market. Each consumer can at most consume one textbook. Buyers are heterogeneous in their preferences for quality. These preferences are represented by $\theta$. $\theta$ is distributed uniformly on $[0, 1]$. A type $\theta$ consumer derives a benefit of $\theta Q$ from consuming a book of quality $Q$ during the first period he enters the market.

$^5$Below a level that is optimal if preferences were perfectly observed and resale was prohibited.
In the second period there are two states of the world \( \omega \in \{h, l\} \). State \( \omega \) occurs with probability \( q_\omega \). The state of the world affects the popularity of the book as a reference. In state \( \omega \) a type \( \theta \) consumer who purchased a book in period 1 will value the used book at \( \theta \tilde{V} \) with probability \( 1 - \rho_\omega \) and zero otherwise.\(^6\) Let \( 1 > \rho_h > \rho_l > 0 \). In each state some consumers value the book as a reference and some do not.

The valuation \( \theta \tilde{V} \) represents the value the student places on keeping the book if they value it as a general reference. The states of the world represent how many students value it as a general reference within the field. When the publisher first publishes the book they don’t know how popular the book will be as a reference book in the second period. When the state of the world is \( l \), fewer students resell the used textbook because more keep the book as a general reference. Therefore, the market share of used textbooks is lower. In state \( h \) the stock of used books in the market is high because fewer consumers value the book as a reference.

If the student does not purchase a current edition, he has the outside option of purchasing a book from the outside market. The stock of older editions is sufficiently large as to force the market price to zero. We assume that all outside books contain the basic materials as the current edition but are in a different format. Therefore they have some value but not as much as a current edition. The quality of the outside market text books is denoted as \( Q_0 \). For students who purchase an older edition in the first period, there is a probability \( 1 - \rho_0 = \sum_{\omega \in \{h,l\}} q_\omega (1 - \rho_\omega) \) they may also wish to keep the book as a reference for future periods. If they do, they will value the book at \( \theta \tilde{V} \).

The publisher is able to sell new textbooks in each of the two periods labeled 1 and 2. Each book has a marginal cost of \( c \) to produce new. To ease notation we denote the book quality above the outside option as \( Q_k \) where \( k = 1, 2, U \). That is, the first period new book quality is \( Q_1 + Q_0 \). In the second period the firm can revise the book or continue to sell the old edition. If the firm sells the old edition the new book quality is \( Q_1 + Q_0 \) and the used book quality is \( Q_U + Q_0 \), where \( Q_1 \geq Q_U > 0 \).\(^7\) If the publisher publishes a new edition he pays a fixed cost \( K > 0 \) and the quality of a new book is \( Q_2 + Q_0 \geq Q_1 + Q_0 \). Publishing the new edition reduces the quality of used books to \( Q_0 \). The publisher and the buyers have a common discount factor of 1 and money is the

\(^6\)We assume that \( \tilde{V} \) is large enough that no students who value the book at \( \theta \tilde{V} \) will sell them in the second period.

\(^7\)The assumption that new books of the same edition have the same quality across periods (i.e. \( Q_1 = Q_N \)) can be relaxed without affecting any results. It may be reasonable that the older edition is less valuable in period 2 just because the information is outdated (i.e. \( Q_1 < Q_N \)).
Consumers have rational expectations. Therefore, the expected sale price of a used book is incorporated into the price of the book in the first period. The presence of used books in the second period creates an important linkage between the periods.

The choices for the publisher include the production decision in the first period and the revision and production decision in each second period state of the world. We denote the revision choice as \( R \subseteq \{h, l\} \) as the set of second period states where the publisher chooses to revise the book. The first period production decision is \( x_1 \) and the state \( \omega \) period 2 production decision is denoted as \( x_{\omega, 2} \).

The timing of the game is as follows. First, the publisher chooses first period production levels and sells to consumers. Second, the second period state of the world is realized and first period consumers learn if they have a high reference value for the book or not. The publisher observes the state of the world and chooses whether or not to revise. Third, the publisher sells second period new books to the new consumers and first period consumer choose whether to sell their used book.

Since the equilibrium prices will depend on the revision and production decision, the publisher’s profits are,

\[
\Pi = x_1 \left[ P_1(x_1, x_{h, 2}, x_{l, 2}, R) - c \right] + \sum_{\omega \in \{h, l\}} q_\omega \left( x_{\omega, 2} \left[ P_{\omega, 2}(x_1, x_{\omega, 2}, R) - c \right] - I_{(\omega \in R)}K \right),
\]

(1)

where \( P_1(x_1, x_{h, 2}, x_{l, 2}, R) \), and \( P_{\omega, 2}(x_1, x_{\omega, 2}, R) \) are the inverse demand functions for new books.

We now derive the market prices for these books based on the publisher’s production and revision decisions. If the firm decides to revise the edition in state \( \omega \), the equilibrium price for new books in that state is,

\[
P_{\omega, 2}(x_1, x_{\omega, 2}, R) = (Q_2 + Q_0)(1 - x_{\omega, 2}) - Q_0(1 - x_{\omega, 2}) = Q_2(1 - x_{\omega, 2}).
\]

(2)

In a state where the firm revises the book, the used books become part of the large stock of previous editions. Since the used first period books are now no longer current, the sale price of the new edition will only be affected by the outside option which is not a close substitute.

If the firm does not revise in the state \( \omega \), the books of the highest quality will be consumed by
the consumers with the $x_{\omega,2}$ highest taste parameters. The used books are consumed by the next $\rho_{\omega}x_1$ highest $\theta'$s. In equilibrium, the consumer with the taste parameter equal to $1 - x_{\omega,2} - \rho_{\omega}x_1$ will be indifferent between buying a used book at the price $P_{\omega,u}(x_1, x_{\omega,2}, R)$ and the outside option. This defines the second period price for used books.

\[ P_{\omega,u}(x_1, x_{\omega,2}, R) = (Q_U + Q_0)(1 - x_{\omega,2} - \rho_{\omega}x_1) - Q_0(1 - x_{\omega,2} - \rho_{\omega}x_1) \]

\[ = Q_U(1 - x_{\omega,2} - \rho_{\omega}x_1). \]

(3) (4)

The new books in period 2 will be sold to consumers with the $x_{\omega,2}$ highest $\theta$s. The consumer with the taste parameter equal to $(1 - x_2)$ will be indifferent between a used book at the price $P_{\omega,u}(x_1, x_{\omega,2})$ and a new book at price $P_{\omega,2}(x_1, x_{\omega,2})$. This defines the new book price in period 2 as,

\[ P_{\omega,2}(x_1, x_{\omega,2}, R) = (Q_1 - Q_U)(1 - x_{\omega,2}) + Q_U(1 - x_{\omega,2} - \rho_{\omega}x_1). \]

(5)

The expected lifetime value of a new book to a period 1 consumer consists of three parts. The first is the use value in the first period. For a consumer with quality preference $\theta$ this use value is $\theta(Q_1 + Q_0)$. The second part of the expected lifetime use value is the expected value as a reference book in period 2 which is $\theta \left( \sum_{\omega \in \{h,l\}} q_\omega (1 - \rho_\omega) \hat{V} \right)$. The third part is the expected resale value in the second period which is, $\sum_{\omega \in \{h,l\}\setminus R} q_\omega \rho_\omega P_{\omega,u}(x_1, x_{\omega,2}, R)$. To determine the first period price, we note that the consumer labeled $(1 - x_1)$ is indifferent between buying a book and not. We also must take into consideration the effect of the outside option. The outside option has the value of $Q_0 (1 - x_1) + (1 - \rho_0) \hat{V}$. The price of a new book in period 1 is,

\[ P_1(x_1, x_{h,2}, x_{l,2}, R) = \left( Q_1 + Q_0 + \sum_{\omega \in \{h,l\}} q_\omega (1 - \rho_\omega) \hat{V} \right) (1 - x_1) \]

\[ - Q_0 (1 - x_1) - (1 - \rho_0) \hat{V} + \sum_{\omega \in \{h,l\}\setminus R} q_\omega \rho_\omega P_{\omega,u}(x_1, x_{\omega,2}, R). \]

(6) (7)

For ease of notation we will define $\sigma_1 = Q_1 + \hat{V} \left( \sum_{\omega \in \{h,l\}} q_\omega (1 - \rho_\omega) - (1 - \rho) \right)$. This expression multiplied by the taste parameter is the expected value of the first period book to the first period consumer above the outside option.
The firm’s profit (1) can now be written as,

\[ \Pi_R = x_1 \left[ \sigma_1 (1 - x_1) - c \right] + \sum_{\omega \in \{ h, l \} \setminus R} q_{\omega} \left( Q_U \rho_{\omega} x_1 \left[ 1 - 2x_{\omega,2} - \rho_{\omega} x_1 \right] + x_{\omega,2} \left[ Q_1 (1 - x_{\omega,2}) - c \right] \right) \]
\[ + \sum_{\omega \in R} q_{\omega} \left( x_{\omega,2} \left[ Q_2 (1 - x_{\omega,2}) - c \right] - K \right) \quad (8) \]

We have defined the profit of the firm based on output and revision decisions in each state of the world. We now analyze welfare levels depending on production and revision decision. In later sections, we examine the firm’s decision under different commitment assumptions and parametrizations.

### 3.1 Social Welfare

In this section we compare the social planner’s objective function to the monopolist’s. Given the revision decision \( R \) and the outputs \( x_1, x_{l,2}, \) and \( x_{h,2} \) we can determine the total value of the market to the consumers. Social welfare can be determined by the use and reference value minus costs in all stages and periods.

We first look at the use value of the books that are sold in a period 2 state \( \omega \) to new consumers. If the firm has revised in state \( \omega \) then the average use value of the \( x_{\omega,2} \) books is \( Q_2 \left( 1 - \frac{x_{\omega,2}}{2} \right) \). Therefore the total value of these books is \( x_{\omega,2} Q_2 \left( 1 - \frac{x_{\omega,2}}{2} \right) \).

If the firm does not revise in state \( \omega \) there are some consumers who value used period 1 books. The average value for the used books is \( Q_U \left( 1 - x_{\omega,2} - \frac{\rho_{\omega} x_1}{2} \right) \). The total value of used books sold in this period is, \( \rho_{\omega} x_1 Q_U \left( 1 - x_{\omega,2} - \frac{\rho_{\omega} x_1}{2} \right) \). The new books have an average use value of \( Q_1 \left( 1 - \frac{x_{\omega,2}}{2} \right) \). The total value of these books to consumers is \( x_{\omega,2} Q_1 \left( 1 - \frac{x_{\omega,2}}{2} \right) \).

New books in period 1 have a use value for that period, plus the expected reference value to period 1 customers. The average use and expected reference value for period 1 consumers is \( \sigma_1 \left( 1 - \frac{x_1}{2} \right) \). The total value of these books to consumers is \( x_1 \sigma_1 \left( 1 - \frac{x_1}{2} \right) \). The total welfare from this market is the total use value minus the marginal and revision costs. That is social welfare is,

\[ W_R = x_1 \left( \sigma_1 \left( 1 - \frac{x_1}{2} \right) - c \right) + \sum_{\omega \in \{ h, l \} \setminus R} q_{\omega} \left( x_{\omega,2} \left[ Q_2 \left( 1 - \frac{x_{\omega,2}}{2} \right) - c \right] \right) \]
\[ + \sum_{\omega \in R} q_{\omega} \left( Q_U \rho_{\omega} x_1 \left( 1 - x_{\omega,2} - \frac{\rho_{\omega} x_1}{2} \right) + x_{\omega,2} \left( Q_1 \left( 1 - \frac{x_{\omega,2}}{2} \right) - c \right) \right) \quad (10) \]
Comparing this to firm profit, social welfare equals,

\[ W_R = \Pi_R + \sigma_1 \frac{(x_1)^2}{2} + \sum_{\omega \in \{k,l\} \setminus \hat{R}} q_\omega \left( Q_U \frac{(x_{\omega,2} + \rho_\omega x_1)^2}{2} + (Q_1 - Q_U) \frac{(x_{\omega,2})^2}{2} \right) + \sum_{\omega \in \hat{R}} q_\omega Q_2 \frac{(x_{\omega,2})^2}{2}. \]  

(11)

We denote the social planner’s revision decision as \( \hat{R} \). Under the assumption that the publisher chooses production. In later sections we discuss how this relates to the publisher’s actual revision decision.

4 Full Commitment

In this section we assume that the firm is able to fully commit to both output and revision. We show how results can differ depending on the substitutability between new and used books of the same edition.

4.1 Perfect Substitutability

The first case that we will explore corresponds to the literature on optimal durability. In these models, consumers do not care directly whether the good is new or used. They only care about the service that the good can provide. In other words, you could give the consumer enough used books to make the buyer indifferent between that and a new book.\(^8\)

Rather than using multiple lower quality books of the same text, it is logical that students use only one book. This condition means that books of the same edition have the same quality whether they are used or new i.e. \( Q_1 = Q_U \).\(^9\) In order to determine the revision choice by the firm, we first look at the optimal production decision for a given revision policy. The firm will then also choose the revision policy that maximizes profits.

Under the assumption \( Q_1 = Q_U \) the profit of the firm (8) simplifies greatly. If the firm does not revise in state \( \omega \), used books can be sold at the same price as new books but at no additional printing cost. Since some of the first period books can be sold twice, the effective cost of a new book is reduced by the second period used book market. The profit function simplifies to,

\[^8\]This is referred to in the literature as the goods being decomposed into ‘service units.’
\[^9\]The qualitative results of this subsection are not dependant on this interpretation of Swan’s assumption, i.e. other more general assumptions would yield the same results.
\[
\Pi_R = \max_{x_1, x_1, x_2, x_2, x_2} \left[ \sigma_1 (1 - x_1) - c + \sum_{\omega \in \{h, l\} \setminus R} q_\omega \rho_\omega c \right] + \sum_{\omega \in \{h, l\} \setminus R} q_\omega (Q_1 \bar{x}_{\omega, 2} [1 - \bar{x}_{\omega, 2}] - c\bar{x}_{\omega, 2}) + \sum_{\omega \in R} q_\omega (x_{\omega, 2} [Q_2 (1 - x_{\omega, 2}) - c] - K(\bar{\omega})) \tag{12}
\]

Where \[\bar{x}_{\omega, 2} = x_{\omega, 2} + \rho_\omega x_1 \text{ for all } \omega \notin R.\] \tag{14}

Now there are no cross product terms between first and second period production decisions. The firm’s optimal production choices are,

\[
x_1 = \frac{Q_1 - c \left(1 - \sum_{\omega \in \{h, l\} \setminus R} q_\omega \rho_\omega \right)}{2Q_1} \tag{15}
\]

\[
x_{\omega, 2} = \begin{cases} 
\frac{Q_2 - c}{2Q_2} & \text{if } \omega \in R \\
\frac{Q_1 - c}{2Q_1} - \rho_\omega x_1 & \text{else}
\end{cases} \tag{16}
\]

If the publisher does not revise, the total number of books sold in the second period is \[x_{\omega, 2} + \rho_\omega x_1 = \frac{Q_1 - c}{2Q_1}.\] Used books on the market perfectly crowd out new book sales. Since the expected resale price is incorporated into the initial book price this cost saving will be greater for states with a larger number of used books in the market.

We again find that the ability to reuse and resell the used product only improves profitability for the producer. The benefit is stronger the more used books available for resale. Therefore under these assumptions, publishers should be less willing to revise when there is a large stock of used books.

**Proposition 1** If \(Q_1 = Q_U\) and the publisher does not revise the book in state \(l\) then it does not revise in state \(h\). Under some conditions the firm revises in state \(l\) only.

**Proof.** In appendix

Through the parameter \(p_\omega\) the state of the world directly affects the number of used books that will be offered to the market. Since \(\rho_h > \rho_l\) the stock of used books will be larger in state \(h\). Therefore, Proposition 1 says that the decision to revise is less profitable when the stock of used books of that edition is large. The cost saving effect of not revising is the root of this result. When the publisher does not revise the edition, used books can be resold at the new book price.
Since commitment is possible, publishers choose a revision policy to maximize lifetime profits. The expected resale price of the used books is incorporated into the first period price. If they do not revise, the publisher can effectively sell the same book in multiple periods, otherwise the used books become valueless.

The publisher may still want to revise the book in the second period if the quality of the new edition $Q_2$ is high enough. This quality difference must be large enough to compensate for the fixed revision costs and the foregone cost saving from reselling used books. These cost savings of not revising are larger when there are more used books in the market. Therefore, if the publisher can commit it will be less likely to kill off the market when there are many used books on the market. In states where there are fewer used books, the cost saving is less and the incentive to revise is greater. The result, that revision is more likely when the stock of used books is small, is inconsistent with the aforementioned work by Iizuka (2007).

Under this variant, it is clear that the publisher would never want to revise the book unless there are meaningful quality improvements. That is, there is no incentive to revise for the sole purpose of 'killing off' the market for used books. The publisher may want to update the book, but it would have to be for a significant quality increase.

### 4.1.1 Social Planner and Swan

Now that we have examined the publisher’s revision decision we can now compare it to the social planner’s. Unlike previous literature on optimal durability, we find that the monopolist chooses too much durability compared to the social planner. This is because the monopolist does not appropriate the difference in consumer surplus from revision.

**Corollary 1** If $Q_1 = Q_U$, then the firm revises in weakly (sometimes strictly) fewer states than is socially optimal.

**Proof.** In Appendix ■

Corollary 1 shows us that firm’s incentive to update will always be less than the benefit to society. Under this variant durability acts as to reduce the effective marginal cost of production. Updating improves quality. Both of these effects move consumer surplus and producer surplus in
the same direction. Therefore, the net social benefit of revision will always be greater than the publisher’s.

This result is somewhat different than the other papers using similar assumptions. They predict that durability choice will be optimal from both the firm and the societal standpoint. Here we predict that revision may be less than socially optimal. This new result comes from the nonstationarity of the quality of subsequent book editions. We have assumed that revised editions have higher value. The publisher revises only if the revised book is of sufficiently higher quality. The benefit of textbook revision is not completely appropriated by the publisher. This results in the possibility of too few revisions from a societal standpoint.

In this section we have shown that the Swan type model makes the empirically inconsistent prediction that the market share of used books will make revision less attractive. Also, the firm will never revise unless there is a significant increase in the quality of the book. Further we found that the firm may conduct fewer revisions than socially optimal.

Although frequent revisions are a common practice in the textbook industry, it seems unlikely that each revision greatly improves product quality. Significant improvements in book quality with each edition may be realistic for some subjects, but not others. This logic combined with the aforementioned empirical results suggest that this variant is not a good approximation of the textbook market.

4.2 Quality Distortions

This section illustrates an important finding in the literature on vertical differentiation or quality distortions (see Mussa and Rosen 1978). When selling to heterogeneous consumers there is often an incentive to distort the quality of lower quality products downward. Other times the publisher may want to not provide lower cost and quality alternatives and only sell to the higher value customers. They do this in order to increase profits made from the higher value consumer.

This reasoning has been extended into markets for durable goods (see Waldman 1996b, 1997; and Hendel and Lizzeri 1999). Lower quality used goods limit the sale value of new goods. By an under investment in durability (which affects secondhand quality), a durable goods monopolist can distort quality downward to increase profits. This lowered quality choice is below what is socially optimal.
This strand of literature on planned obsolescence has often referred to the textbook market as an example of this type of durability distortion. One way that publishers may want to distort durability is by designing books to wear out faster. Books may have tear out problem sets or online material that expires after one use. This type of durability reduction will be discussed as an extension in section 4.4.

While limiting durability through product design is possible, another way to lower the used book value is by publishing a new edition. Since the old editions may not be readily available to all students, instructors usually assign current versions. If the current editions are often different enough from previous editions, and students are forced to purchase the new edition. The material covered from one edition to the next may be the same, but minor differences such as page numbers and questions can be different. If the student wants to keep up with the instructor’s lectures, having the right book is crucial. Therefore even though older editions may be less expensive and have much the same information, they are not a close substitute for the current edition.

As in the previous subsection, printing costs will make revising less attractive. Even with quality distortions, the marginal cost savings of not revising may be significant. In states where there are a lot of used books in the second period, the marginal printing cost makes revising less attractive. However the presence of lower quality used books in the market reduces the profitability of the publisher. Increasing the quantity of such used books can make revision more attractive.

Proposition 2 If \(Q_1 > Q_U > 0\) and \(c \leq \frac{1}{2}(\rho_h + \rho_l)(Q_1 - Q_U)\), if it is optimal for the publisher to revise the book in state \(l\) then it is also optimal for it to revise in state \(h\). Under some parameter conditions, revision only happens in state \(h\).

Proof. In appendix ■

The used books in the market have two competing effects on profitability. The first as illustrated in the previous model is the cost saving effect. The second effect is the quality distortion effect. The presence of the lower quality used books in the market limits the profit the publisher gains on the high value consumer. This effect worsens with the number of used books.

The effect used books have on the revision decision will depend on which of these two forces are stronger. Proposition 2 gives us a sufficient condition for revision to be more likely with a larger stock of used books. This is when the marginal printing cost is small relative to the difference in
new and used book quality. As before, not killing off the secondary market can reduce marginal costs. However if marginal costs are low relative to the quality difference between new and used books then there may also be an incentive to eliminate these books altogether. This is true even if the consumers are forward looking.

If the marginal costs are large relative to the new and used book quality difference then this result need not hold. We know from Proposition 1 that when used and new books have the same quality that revision for low numbers of used books in the market is more likely. Due to the continuous nature of this model, we get the same result when used and new book qualities are sufficiently close or when marginal costs are sufficiently high.

Empirical evidence suggests that a large quantity of used books in the market will make revision more likely. Under many parametrizations, this model is able to generate predictions that are consistent with the empirical findings. Proposition 2 provides sufficient conditions for this to hold.

Thus far in this paper we have discussed that cost savings makes revision less attractive while the incentive to distort used book quality makes revision more attractive. We now show that this distortion can be strong enough so that the firm may want to revise the book even if there is no improvement in new book quality. That is, a publisher may choose to revise the book for the sole purpose of "killing off" the market for used books.

Proposition 3 If the marginal cost is small \( c < \frac{\rho_2 Q_1 \sigma_1}{\sigma_1 \sigma_1 + \rho_2 Q_1} \) for some \( \omega \in \{l, h\} \) then there exists some \( \tilde{Q} \in (0, Q_1) \) such that when \( 0 < Q_U < \tilde{Q} \) the publisher has an incentive to revise the book in state \( \omega \) even if the quality difference is zero (i.e. \( Q_1 = Q_2 \))

Proof. In Appendix  ■

Proposition 3 defends the belief that the used product market can harm profits. It states that if the used book quality is low enough (but not zero) the publisher will be willing to pay a positive revision cost in order to devalue the used books.

4.3 Pricing Under Full Commitment

Another way to determine which model best describes the textbook market is through the prices set by the publisher. Here we look at the relationship between the stock of used books in the market
and the price of used and new books. We then compare these predictions against the empirical findings of Bond and Iizuka (2005).

**Lemma 1** If the publisher can fully commit, if the publisher does not revise in the second period then,

1) The used book price is not affected by the stock of used books in the market.
2) If new and used books are not perfect substitutes (i.e. $Q_U < Q_2$) the quantity of used books in the market increases the price of new 2nd period books.
3) If new and used books are perfect substitutes then the quantity of used books have no effect on new book price. New and used book price will be equal.

Lemma 1 states that under full commitment only when used and new books are of different quality will the stock of used books affect price. If this is true then the stock of used books should increase new book price. This is because when the stock of used books is larger the firm will not be as competitive selling new books to lower taste consumers. They will focus more on selling new books buyers with a higher taste for quality.

This result is consistent with the empirical result found by Bond and Iizuka (2005). They find that the share of new books in the market increases the new book price. This result combined with Lemma 1 suggests that perfect durability does not describe the textbook market. There is perhaps a more obvious reason to believe that in the real world, new and used text books are not perfect substitutes. A trip to any college bookstore will quickly reveal that used and new copies of the same edition are seldom if ever sold for the same price. If new and used books were valued equally it is unclear why there would be such a difference in their prices.

We have argued that these results on prices argue against perfect durability. In a later section we use these results to distinguishing between the quality difference and time inconsistency models.

### 4.4 Reducing Durability Through Design

Frequent revision is not the only way that publishers have been accused of employing planned obsolescence. One common accusation against textbook publishers is that they design the textbook to limit its future value. Some of these practices include tear-out pages or bundling with electronic services that expire after a one time use. In this section we show that reducing durability in the
product design phase may or may not improve profitability. We find that under the perfect substitute assumption the publisher will never reduce durability. However, if this or the full commitment assumption is not satisfied, a reduction in durability can improve profitability.

The publisher has the ability to reduce second period quality from $Q_U$ to a fixed $\eta Q_U$ where $0 < \eta < 1$. This quality reduction can be done costlessly and must be decided prior to first period production.

We find that the incentive to reduce durability depends on the default durability level. Our benchmark will be the optimal durability assumption. That is we first look at the incentive to reduce used book quality below perfect durability.

**Proposition 4** If the initial used book quality $Q_U$ is the same as the new book quality $Q_1$ then the firm will never reduce durability.

**Proof.** In Appendix

Similar to the results on revision Proposition 4 the publisher has no incentive to reduce book durability. Reducing the quality of the used book away from new quality has two effects on profits. First since the used books are less valuable they will sell at a lower price. Second, reducing the value of the used books will increase the price consumers are willing to pay for new books. We find the first effect will always be stronger when moving away from perfect durability.

It seems that durability reductions have become increasingly more popular among publishers. This suggests that perfect durability is not the correct model variant.\(^{10}\)

We have shown that publishers will never reduce durability away from perfect durability. It may however be profitable for publishers to further reduce durability on less than perfectly durable books. We now show that quality reductions can improve profits when used books are always less than perfect substitutes for new books.

**Proposition 5** If the marginal cost of printing a book is small, then there exists some $0 < \bar{Q}_U < \frac{1}{2} Q_1$ such that for all initial $Q_U \leq \bar{Q}_U$ and all $\eta \in (0,1)$, the publisher has an incentive to reduce profitability.

\(^{10}\) Also it seems implausible that even hardcopy textbooks could ever survive any period of college life without some wear and tear.
Proof. In Appendix ■

Proposition 5 gives a sufficient condition to when it will be profitable for the firm to reduce durability of used books. This happens when the used books are already of low quality and marginal cost of printing the book is sufficiently small.

For any revision policy where the publisher does not revise in some state, we find the profit function is U shaped with respect to used book quality \( Q_U \).\(^{11}\) As mentioned before there are two effects of a reduction on \( Q_U \) on profits. First, the expected resale value of the book is paid to publisher when initially sold. This naturally increases with the quality of the used book. Second the quality of the used book negatively affects customer’s willingness to pay for high quality new books. When used book quality is high enough, the first affect dominates. In fact, profits are always greatest when the books are perfectly durable. But, if used book quality is sufficiently low, the second effect dominates. It becomes profitable to further reduce durability.

If publishers are able and choose to reduce durability it affects the optimal number of books sold in both periods.

**Corollary 2** If firms reduce durability, the number of books sold in both first and second periods increases.

Proof. In Appendix ■

Corollary 2 states that publishers that use durability reductions to improve profits sell more new books in both periods than they would have if this were not possible. This comes as a direct result of the breaking down of the link between used and new book sales. As a result of the durability reduction there is less crowding out of new books by used books. The publisher sells more new books in the second period than they would if durability reductions were not possible. Also books sold in the first period have fewer adverse effects on second period profits. Therefore, more new books are sold in the first period.

5 Time Inconsistency

So far in this paper we have assumed that the publisher is able to commit to future actions. This assumption assumes away any time inconsistency with respect to the publisher. We now relax this

\(^{11}\)This is true if the marginal cost \( c \) is sufficiently small. Otherwise the function is monotonically increasing.
assumption in order to address an important strand in the durable goods literature.

In this section, the publisher can not commit to second period actions in the first period. At the beginning of the 2nd period the firm observes the state of the world and chooses to whether or not to revise and second period quantity. In this analysis we assume (as in the optimal durability model) that used and new books of the same edition are perfect substitutes. However all results and analysis are identical when we allow used books to be of lesser quality.

Since the publisher makes its second period decision in the second period, it does not appropriate the effect of its decisions on first period profits. Each used book in the second period market is a substitute for the new book. Therefore from the profitability of the publisher in the second period, all used books lower profits. Since the publisher is able to eliminate these books through a revision, the incentive to do so is stronger when there are more books in the market. These actions may be suboptimal for the firm from the first period perspective. We now show that without commitment, the publisher will be more likely to update when the stock of used books is higher.

**Proposition 6** *If the publisher does not have the ability to commit to period 2 actions, it will never revise in state l only. Under some conditions it will only revise in state h.*

**Proof.** In Appendix ■

Without commitment to future production levels, the firm will produce more books in the later periods than would maximize first period profits. This result is known in the literature as Coasian dynamics.

The overproduction of books in the later period is not the only source of time inconsistency. Also firms will choose to revise in the second period when it may not be optimal from a first period perspective.

The stock of used books has an unambiguous affect on the incentive for firms to revise. Consistent with Iizuka (2007), it predicts that revision is more profitable when the stock of used books is high.

Without commitment, it is easy to see a publisher’s incentive to devalue the quality of used books in the market to zero. Each used book reduces second period profit. Therefore the publisher will always be willing to pay in order to eliminate this competition. This is true whether the revision improves book quality or not.
Proposition 7 If \( K \leq \frac{(Q_1-c)^2}{4Q_1} - \left( Q_1 - \rho_u Q_U \frac{c' - c}{4Q_1} \right)^2 \) then the firm will revise in state \( \omega \) even if there is no quality improvement (i.e. \( Q_2 = Q_1 \)).

Proof. In Appendix ■

Proposition 7 gives a much stronger prediction on when the publisher would want to "kill off" the market for used books. Since the firm does not consider this affect on first period profits, it has a significant incentive to eliminate competition with the used books.

5.1 Pricing Under No Commitment

The time inconsistency model and the quality difference model both suggest a need for frequent revision, durability reduction, and leasing. Therefore it is somewhat difficult to distinguish which model better fits the data. The effect of used books on new book prices allows us to distinguish between the two models of planned obsolescence. We then compare these predictions against the empirical findings of Bond and Iizuka (2005).

Similar to the Coase conjecture (1972) we find that increasing the stock of used books will result in lower prices.\(^\text{12}\)

Lemma 2 If the publisher cannot fully commit and the publisher does not revise in the second period then,

1) The used book price is negatively affected by the stock of used books in the market.

2) An increase in the quantity of used books decreased the price of new books as long as the used books are a close enough substitute to new books (i.e. \( Q_u > \frac{Q_1}{2} \)).

The used books in the market effectively reduces the demand for new books. Under no commitment the firm only considers 2nd period profits when making its pricing (and production) decision. More used books means that the demand for new books has been reduced even more thus reducing the publishers 2nd period price.

Lemma 2 combined with the earlier Lemma 1 gives clear predictions on how used books affect new book price. The empirical findings of Bond and Iizuka (2005) are only consistent with the

\(^{12}\)The Coase Conjecture discusses how the prices of the good decreasing over time as the stock of the used good increases. Our model is only two periods, but we show that when there is a shock that increases the stock of used books this causes the monopolist to reduce prices in a similar way.
quality difference variant of our model. They find that used books in the market increase the price of new books in the market. Recall from Lemma 1 that this is true when firms can commit to future decisions and used and new books are imperfect substitutes. From Lemma 2 we get the opposite relationship when firms cannot commit to future output.

5.2 Reducing Durability Through Design (Time Inconsistency)

The durability decision is made before the books are sold. Therefore, durability not subject to time inconsistency the way in the same way as production or revision. However the publisher’s decisions in later periods will change the effect of durability reductions on profitability. The quantity and quality of used books affects the second period production and revision decision. The publisher must take into consideration how current actions will affect future decisions.

In order to isolate the time inconsistency aspect of the durability decision we will start with the assumption that books can be perfectly durable. Also let us first assume that the firm is able to commit to a future revision decision but not future production. This assumption may seem reasonable since revision is a large observable event and could be contractible where this might be impossible for output. We now show that small reductions away from perfect durability reduces publisher profits.

**Proposition 8** If the initial used book quality $Q_U = Q_1$ and the firm can commit to a revision decision, then the firm will never intentionally reduce book quality as long as the potential reduced used book quality is greater than $\frac{2}{3}Q_1$.

**Proof.** In Appendix ■

The Proposition 8 is analogous to Proposition 4 however somewhat weaker. This weakness comes from the time inconsistency. In addition to the two previously discussed effects, durability reductions now alleviate pressures caused by Coasian dynamics.\textsuperscript{13} If the link between period is weakened through reduced durability the second period publisher’s tendency to overproduce becomes less of a problem. Although durability reductions now have an addition benefit, Proposition 8 shows that a small movement away from perfect durability lowers profits. That is the effect on

\textsuperscript{13}Coasian dynamics refers to the tendency of durable goods monopolists to sell more in later periods than would optimize the expected future profits from a firm’s earlier viewpoint.
initial book price dominates is greater than the other effects combined. However large reductions in durability can improve profits if the marginal cost of selling books is small.

Now we examine the model when firms are unable to commit to a revision policy or second period output. When such commitments are not possible first period quantity restriction can serve as a commitment device. We find in some cases that even a small reduction in durability can improve profitability by increasing optimal first period output.

In the second period used books are substitutes for new books and reduce second period profit. The second period revision decision depends only on the profits in the second period. The effect on price of the resale value of used books of first period books is not appropriated in the revision decision. If the publisher does not revise, resale values are positive. Therefore the publisher can revise too frequently in the second period.

As with many time inconsistency problems commitment devices can be useful. The effect on the expected revision decision on first period prices proves as an incentive for the firm to restrict output in the first period. Suppose that for a given quantity of used books, revision is only slightly more profitable for the firm in the second period. That is, if the stock of used books were a little smaller the firm would choose not to revise. Since the expected profits in the first period include resale value, there is an incentive for the publisher to reduce first period quantity to commit itself to not revising in the future. This would result in a marginal increase in expected second period profits and a significant increase in the price consumers are willing to pay for the book in the first period. Any further marginal reduction in quantity beyond this trigger amount only lowers profits. Therefore the publisher may often produce first period output just at the point where it can commit its future self to not revise in some future state \( \omega \).

For a publisher that is committing itself to not revise in some future state, durability reduction can serve as a substitute for first period quantity reduction. Reducing durability will naturally reduce the resale value of first books and subsequently the initial price of such books. However by reducing durability the firm can sell more books in the first period without causing revision in the second period.

**Proposition 9** *If the publisher is unable to commit to future actions, firm maximizes 2nd period profit for any stock of used books, and the following hold*
1) \[ x_1^* = \frac{Q_1 - c - \sqrt{\frac{c}{Q_2} (Q_2 - c)^2 - 4K}}{Q_U \rho_\omega} \] uniquely maximizes expected lifetime profit,

2) \[ Q_1 - c - \sqrt{\frac{c}{Q_2} (Q_2 - c)^2 - 4K} \rho_\omega < \frac{Q_1 - c + \sum_{\omega \in \{(h, j)\} \setminus R} q_\omega Q_U \rho_\omega}{2 \left[ \frac{Q_1}{Q_U} + \frac{1}{2} \sum_{\omega \in \{(h, j)\} \setminus R} q_\omega (\rho_\omega)^2 \right]}. \]

3) \[ Q_1 - c - \sqrt{\frac{c}{Q_2} (Q_2 - c)^2 - 4K} \rho_\omega < \frac{Q_1 - c}{2 \left[ \frac{Q_1}{Q_U} + \frac{1}{2} \sum_{\omega \in \{(h, j)\} \setminus R} q_\omega (\rho_\omega)^2 \right]^2}. \]

then there exists some \( \eta \in (0, 1) \) such that the publisher can increase profits by reducing used book quality \( Q_U \) to any value above \( \eta Q_U \).

Proposition 9 shows that profits can increase even for small movements away from perfect durability. This happened through the relaxing of the low first period output condition.

The conditions for this proposition are very important and have a natural interpretation. Condition 1) states that the given no quality reduction (i.e. \( Q_1 = Q_U \)) the optimal first period production results in the highest used book quantity where the firm does not revise in some state \( \omega \). Also this first period quantity uniquely maximizes the problem. Condition 2) is related to it. Condition 2) states that first period output is lower than if the firm could commit to not revise in period 2 (again given no quality reduction). That is, the reduction in quantity is a commitment device that costs the firm through fewer sales. Condition 3) concerns effect of reducing durability \( (Q_U) \) away from perfect durability. There are two affects of such a reduction. First, durability reductions ease the first period quantity restrictions. Second reducing durability lowers resale value and thus the price consumers are willing to pay in the first period. Condition 3) states that the effect of easing the quantity restriction on profits must be greater than the effect of quantity. Therefore, we have now shown that additional durability reductions in the design phase are only profitable under conditions of time inconsistency or imperfect durability.

6 Leasing

Another recent phenomena in the textbook market is the increasing amount of leasing. Students are able to rent textbooks for the semester then return them after they are done. Some of these arrangements are done through third party businesses such as chegg.com. Others are done directly through the publishers.

Our model has little to say about third party leasing. But, there are likely reasons for leasing
that lie outside the scope of our model. For example, students may have higher capital cost than a much larger firm. Getting the book to use during the semester requires less up front capital if only rented. Another reason for third party leasing may be a type of insurance for the student. Since it may be unclear exactly when the publisher will revise, there is some financial risk involved when hoping to resell the book. Third party lessors may be willing to take that risk. While these issues may be valid and important they are not fully explored in our current model.

In addition to third party leasing, leasing by the publisher has recently also been increasing. Our model can explain the use of leasing contracts directly between the publisher and the student for both the quality difference and time inconsistency specifications. Since we feel that the quality difference model fits best we discuss leasing in that context first. Our results are similar to previous results durable goods literature (ex. Hendel and Lizzeri 1999, and Waldman 1996b). We find that leasing can improve profits if it allows for the reduction in the resale of used books.

**Proposition 10** If printing costs are large relative to the difference in used and new book quality leasing will improve profits.

The intuition behind Proposition 10 is that leasing allows the firm more control over quantities in the 2nd period market. When the firm sells a book in the first period and the book is sold again in the second the used book is placed on the market at zero cost. Since the resale price of the used book is part of first period profits we can decompose the market as profits made on first period and 2nd period students. Suppose the publisher leases in the first period and resells in the second. In the second period it is as if the firm produces and sells multiple book qualities at different marginal costs. However the publisher can only sell up to the returned number of used books. If it is always optimal to resell all used books then there is no reason to lease in the first period. The resell price would have been incorporated in the first period sell price and profits would be the same. However for some state $\omega$ the profit maximizing number of used books resold may be below the entire stock. In this case, the firm would improve profits by limiting (but not entirely eliminating) the used books on the market. The benefits to leasing do not require the publisher to lease to the entire market. Optimal profits can be reached if leased to enough of the market to be able to sufficiently reduce quantity when needed. The publisher uses leasing to achieve the profit maximizing mix of used and new books in the market.
The reason to lease is somewhat different in the time inconsistency model. This goes directly back to the pioneering work by Coase (1972). By leasing, the publisher can eliminate the negative effects of future decisions on expected earlier profits. By leasing the publisher can eliminate the tendency to overproduce. By leasing, the resell (or lease) value of used books in later periods is accrued to the publisher in that period. By maximizing profits in each period the firm can now maximize profits as a whole. Unlike the earlier result maximal profits are only attained if the firm leases to the entire market. Any used books that are resold by the consumers create the same distortions previously discussed. Therefore, if this model were correct we would expect the publisher to lease to as much of the market as possible.

7 Conclusion

In this paper we revisit the common belief that textbook publishers revise frequently in order to “kill off” the market for used books. While this view has been around for quite some time, there is an influential strand of literature in durable goods theory that challenges this idea. These alternative theories argue that both durability decisions and revision decisions are socially optimal.

In this paper we challenge the optimal durability theory when applied to the textbook market. Recent empirical findings show that publishers are more likely to revise when the market share of used books increases. We show that the theories of the textbook market based on optimal durability are inconsistent with these findings.

Another strand of literature suggest that frequent revisions happen as a result of an inability of the firm to commit to future actions. We find that under this assumption new book price must be negative related to the stock of used books in the market. These predictions do not hold up when compared to the empirical evidence. The only variation of the model that is broadly consistent with the data is full commitment and imperfect substitutability between used and new books.

In addition to new book revision we consider the increasingly common practices of durability reduction and leasing. We show that neither of these will be profitable if firms are able to commit and unaltered books are perfectly durable. But they can improve profits under the other two variants. The presence of these quality reducing practices serves as further evidence that the optimal durability model does not accurately describe the textbook market.
A Appendix

Proof. Of Proposition 1. Given the revision choice of the firm, the optimal second period production decision must solve the first order condition,

$$x_{\omega,2} = \begin{cases} \frac{Q_2-c}{2Q_2} & \text{if } \omega \in R \\ \frac{Q_1-c}{2Q_2} - \rho_{\omega}x_1 & \text{else} \end{cases}$$

Substituting this back into the profit function gives us

$$\Pi = \max_{x_1} x_1 \left[ Q'(1-x_1) - c \right] + \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \frac{Q_U}{Q_1} \rho_{\omega} x_1 [c - \rho_{\omega}x_1 (Q_1 - Q_U)]$$

$$+ \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \frac{(Q_1-c)^2}{4Q_1} + \sum_{\omega \in R} q_{\omega} \left( \frac{(Q_2-c)^2}{4Q_2} - K \right)$$

If we know that $$Q_1 = Q_U$$ this reduces the expression to

$$\Pi = \max_{x_1} x_1 \left[ Q'(1-x_1) - c \right] + \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \left( \frac{(Q_1-c)^2}{4Q_1} + \rho_{\omega}x_1 c \right) + \sum_{\omega \in R} q_{\omega} \left( \frac{(Q_2-c)^2}{4Q_2} - K \right)$$

If we know that revision is optimal in state $$l$$, this means that if we fix $$x_1$$ at the optimal $$x_1^*$$ the profit for not revising in state $$l$$ will be lower than the profit for updating at $$l$$. That is,

$$\frac{(Q_1-c)^2}{4Q_1} + \rho_l x_1^* c \geq \frac{(Q_2-c)^2}{4Q_2} - K$$

This and $$\rho_h > \rho_l$$ imply that, at that same $$x_1^*$$ the publisher will always make more profits by not revising in state $$h$$. This condition is strict whenever $$c > 0$$. Therefore if the publisher does not revises in state $$l$$ he must also not revise in state $$h$$.

We will now show under certain conditions the publisher will revise only in state $$l$$. We know that given the revision decision $$R$$ the optimal choice for $$x_1 = \frac{Q_1-c}{2Q_1} \left(1 - \frac{1}{\omega \in \{h,l\} \setminus R} q_{\omega} \rho_{\omega} \right)$$. We also know that if the firm were to update in state $$h$$ it would also update in state $$l$$. Therefore to show that the firm revises in only state $$l$$ we only need to show that revising in only $$l$$ is more profitable than
not revising at all or revising in both $h$ and $l$. Now we will assume that

$$(\rho_h - \rho_l) \left( \frac{\sigma_1 - c}{2\sigma_1} + \frac{q_h \rho_h}{4\sigma_1} \right) > \frac{c \rho_l}{4\sigma_1} (q_h \rho_h + q_l \rho_l) \Rightarrow
$$

$$\rho_h c \left( \frac{\sigma_1 - c}{2\sigma_1} + \frac{q_h \rho_h}{4\sigma_1} \right) > \rho_l c \left( \frac{\sigma_1 - c}{2\sigma_1} + \frac{q_l q_h h}{4\sigma_1} + \frac{c (q_h \rho_h + q_l \rho_l)}{4\sigma_1} \right)
$$

let $\sigma_1 \rho_h c \left( \frac{\sigma_1 - c}{2\sigma_1} + \frac{q_h \rho_h}{4\sigma_1} \right) > A > \sigma_1 \rho_l c \left( \frac{\sigma_1 - c}{2\sigma_1} + \frac{c q_h \rho_h}{2\sigma_1} + \frac{c q_l \rho_l}{4\sigma_1} \right).

We will now introduce notation $x_1^R$ as the optimal first period production decision given the revision decision $R$. $x_{\omega,2}^R$ is the optimal period 2 production decision in state $\omega$ given $R$. $A = \left(Q_2 \left(\frac{Q_2 - c}{2Q_2}\right)^2 - Q_1 \left(\frac{Q_1 - c}{2Q_1}\right)^2 - K\right).

\[
A > \sigma_1 \rho_l c \left( \frac{\sigma_1 - c}{2\sigma_1} + \frac{q_h \rho_h}{4\sigma_1} + \frac{c (q_h \rho_h + q_l \rho_l)}{4\sigma_1} \right) \Rightarrow
\]

\[
q_l A > \sigma_1 \left( q_l \rho_l c \left( x_{\omega,1}^{(l)} + \frac{c q_h \rho_h}{4\sigma_1} \right) + \left( x_{\omega,1}^{(l)} \right)^2 - \left( x_{\omega,1}^{(l)} \right)^2 \right)
\]

\[
= \sigma_1 \left( \left( x_{\omega,1}^{(l)} \right)^2 - \left( x_{\omega,1}^{(l)} \right)^2 \right) \Rightarrow
\]

\[
q_l K < \sigma_1 \left( \left( x_{\omega,1}^{(l)} \right)^2 - \left( x_{\omega,1}^{(l)} \right)^2 \right) + q_l Q_2 \left( \frac{Q_2 - c}{2Q_2} \right)^2 - q_l Q_1 \left( \frac{Q_1 - c}{2Q_1} \right)^2
\]

Note that $x_{\omega,1}^{(l)} = \left( x_{\omega,1}^{(l)} + \frac{c q_h \rho_h}{2\sigma_1} \right)$. This says that under these conditions it is more profitable to revise in only state $l$ than not at all. Now we can use the other side of the inequality to show that it is better to revise in only state $l$ than in both states

\[
q_h A < \sigma_1 \left( q_h \rho_h c \left( \frac{\sigma_1 - c}{2\sigma_1} + \frac{q_h \rho_h}{4\sigma_1} \right) + \left( x_{\omega,1}^{(l,h)} \right)^2 - \left( x_{\omega,1}^{(l,h)} \right)^2 \right)
\]

\[
= \sigma_1 \left( \left( x_{\omega,1}^{(l)} \right)^2 - \left( x_{\omega,1}^{(l,h)} \right)^2 \right) \Rightarrow
\]

\[
q_l K > \sigma_1 \left( \left( x_{\omega,1}^{(l,h)} \right)^2 - \left( x_{\omega,1}^{(l)} \right)^2 \right) + q_l Q_2 \left( \frac{Q_2 - c}{2Q_2} \right)^2 - q_l Q_1 \left( \frac{Q_1 - c}{2Q_1} \right)^2
\]

Here the gains for revising in period $h$ are smaller than the fixed revision costs. $Q_2 \left(\frac{Q_2 - c}{2Q_2}\right)^2 = \pi_{2, revise}, Q_1 \left(\frac{Q_1 - c}{2Q_1}\right)^2 = \pi_{2, no revise} \blacksquare
Proof. of Corollary 1. Recall that the firm's profit is

$$\Pi_R = \max_{x_1, x_{1,2}^+} x_1 \left[ \sigma_1(1 - x_1) - c + \sum_{\omega \in \{h,l\}\setminus R} q_\omega \rho_\omega c \right]$$

$$+ \sum_{\omega \in \{h,l\}\setminus R} q_\omega (Q_1 \bar{x}_{\omega,2} [1 - \bar{x}_{\omega,2}] - c \bar{x}_{\omega,2}) + \sum_{\omega \in R} q_\omega (x_{\omega,2} [Q_2 (1 - x_{\omega,2}) - c] - K(20))$$

Where $\bar{x}_{\omega,2} = x_{\omega,2} + \rho_\omega x_1$ for all $\omega \notin R$.

Where $\bar{x}_{\omega,2} = x_{\omega,2} + \rho_\omega x_1$. Substituting the optimal $x_1$, and $x_{\omega,2}$ this simplifies to

$$\Pi = \max_{x_1, x_{1,2}^+} \sigma_1(x_1)^2 + \sum_{\omega \in \{h,l\}\setminus R} q_\omega Q_1 \left( \frac{Q_1 - c}{2Q_1} \right)^2 + \sum_{\omega \in R} q_\omega \left( Q_2 \left( \frac{Q_2 - c}{2Q_2} \right)^2 - K \right). \quad (21)$$

Since we know that the publisher will always revise in state $l$ if he revises in state $h$ we only have to look at increasing the number of states that he revises. We compare profits between revising in state $\omega$ or not (keeping the revision decision in the other state fixed). If the publisher does not revise in $\omega$, $\bar{x}_1$ is the optimal first period production. If revise then $\bar{x}_1$. The publisher will choose to revise in $\omega$ if

$$\sigma_1(\bar{x}_1)^2 - \sigma_1(\bar{x}_1)^2 + q_\omega \left( Q_1 \left( \frac{Q_1 - c}{2Q_1} \right)^2 - Q_2 \left( \frac{Q_2 - c}{2Q_2} \right)^2 \right) \geq q_\omega K$$

The social planner decision is to revise if

$$\frac{3}{2} \left[ \sigma_1 \bar{x}_1 - \sigma_1 \bar{x}_1 + q_\omega \left( Q_1 \left( \frac{Q_1 - c}{2Q_1} \right)^2 - Q_2 \left( \frac{Q_2 - c}{2Q_2} \right)^2 \right) \right] \geq q_\omega K$$

This reasoning can be applied to the choice between never updating in period 2 and always updating in period 2. Since $K$ is positive, the publisher will always choose to update weakly less than is socially optimal. For certain values of $K$ this result may be strict. ■

Proof. of Proposition 2. Proof by contradiction. Suppose that the firm revises in $l$ but not in $h$. This implies that at the optimum $x_1^*$,

$$\frac{(Q_1 - c)^2}{4Q_1} + \frac{Q_U}{Q_1} \rho_h x_1^* [c - \rho_h x_1^* (Q_1 - Q_U)] \leq \frac{(Q_2 - c)^2}{4Q_2} - K$$
and
\[
\frac{(Q_1 - c)^2}{4Q_1} + \frac{Q_U}{Q_1} \rho_h x_1^* [c - \rho_h x_1^*(Q_1 - Q_U)] \geq \frac{(Q_2 - c)^2}{4Q_2} - K
\]

Combining these inequalities This implies that
\[
\rho_h [c - \rho_h x_1^*(Q_1 - Q_U)] \geq \rho_1 [c - \rho_1 x_1^*(Q_1 - Q_U)]
\]
\[
c (\rho_h - \rho_i) \geq x_1^*(\rho_1^2 - \rho_i^2) (Q_1 - Q_U)
\]
\[
c \geq x_1^* (\rho_h + \rho_i) (Q_1 - Q_U)
\]
\[
x_1^* \leq \frac{c}{(\rho_h + \rho_i) (Q_1 - Q_U)}
\]

Given that the firm will only revise in state \(l\) the first derivative of the objective function (17) with respect to \(x_1\) is
\[
\frac{d\Pi}{dx_1} = \sigma_1 (1 - 2x_1) + q_l \frac{Q_U}{Q_1} \rho_1 [c - \rho_l 2x_1 (Q_1 - Q_U)] .
\]
evaluate this at \(x_1^* = \frac{c}{(\rho_h + \rho_i) (Q_1 - Q_U)}\)
\[
\frac{d\Pi}{dx_1} = \sigma_1 \left( 1 - \frac{c}{2(\rho_h + \rho_i) (Q_1 - Q_U)} \right) + q_l \frac{Q_U}{Q_1} \rho_1 \left[ 1 - \frac{2\rho_l}{(\rho_h + \rho_i)} \right] > 0
\]

whenever \(c \leq \frac{1}{2} (\rho_h + \rho_l) (Q_1 - Q_U)\). Since the objective function is a simple quadratic function of \(x_1\), the optimal \(x_1\) must be greater than \(\frac{c}{(\rho_h + \rho_i) (Q_1 - Q_U)}\). This is a contradiction.

Here I need to show that at times the firm will want to revise only in period \(h\). let us compare the optimal choice if revise in \(h\), and \(l\), keeping the same production decision for \(x^{(h,l)}_1\), let us show that the firm is better off not revising in \(l\). That is we need to show
\[
\frac{(Q_1 - c)^2}{4Q_1} + \frac{Q_U}{Q_1} \rho_l x_1^{(h,l)} [c - \rho_l x_1^{(h,l)} (Q_1 - Q_U)] > \frac{(Q_2 - c)^2}{4Q_2} - K
\]

here \(x_1^{(h,l)} = \frac{Q_1-c}{2Q_1}\), if \(\frac{(Q_1-c)^2}{4Q_1} - \frac{(Q_2-c)^2}{4Q_2} > -K\) and \(c \geq \rho_l \frac{Q_1-c}{2Q_1} (Q_1 - Q_U)\) then this inequality is satisfied.

The other condition that we need to show is that the firm is more profitable updating in state
The derivative of this expression with respect to the revised book are the same and

Of Proposition 3. The pro...t for a revision plan

\[ h \text{ then never updating at all. Therefore we need to show,} \]

\[
\frac{(Q_1 - c)^2}{4Q_1} + \frac{Q_U}{Q_1} \rho_h x_1^0 \left[ c - \rho_h x_1^0 (Q_1 - Q_U) \right] < \frac{(Q_2 - c)^2}{4Q_2} - K
\]

\[ x_1 = \frac{Q' - c + \sum_{\omega \in \{h,l\}} \frac{Q_U}{Q_1} \omega \rho_{\omega} - c}{2\left(Q' + \frac{Q_U}{Q_1} (Q_1 - Q_U)\right)} > \frac{\frac{Q' - c}{2\left(Q' + Q_U\right)}}{2\left(Q' + \frac{Q_U}{Q_1} (Q_1 - Q_U)\right)} > \frac{\frac{Q' - c}{2\left(Q' + Q_U\right)}}{2\left(Q' + Q_U\right)}
\]

Therefore if \( c < \rho_h \frac{Q' - c}{2\left(Q' + Q_U\right)} (Q_1 - Q_U) \), then this derivative is less than zero. If the quality of new un revised book and

\[ 0 \text{ There also needs to have} \]

\[
-K > \frac{(Q_1 - c)^2}{4Q_1} - \frac{(Q_2 - c)^2}{4Q_2} > -K + \frac{Q_U}{Q_1} \rho_h \frac{Q' - c}{2\left(Q' + Q_U\right)} (Q_1 - Q_U)
\]

The sufficient conditions for revision in only period \( h \) are,

\[
c \leq \frac{1}{2} (\rho_h + \rho_l) (Q_1 - Q_U) \text{ This guarantees if revision in } l \text{ then also in } h
\]

\[
c \geq \rho_l \frac{Q_1 - c}{Q_1} (Q_1 - Q_U)
\]

\[
c < \rho_h \frac{Q' - c}{2\left(Q' + Q_U\right)} (Q_1 - Q_U)
\]

\[
-K > \frac{(Q_1 - c)^2}{4Q_1} - \frac{(Q_2 - c)^2}{4Q_2}
\]

\[
> -K + \frac{Q_U}{Q_1} \rho_h \frac{Q' - c}{2\left(Q' + Q_U\right)} (Q_1 - Q_U)
\]

\[
\]

**Proof.** Of Proposition 3. The profit for a revision plan \( R \)

\[
\Pi_R = \max_{x_1, x_1, x_2, x_h} x_1 \left[ \sigma_1 (1 - x_1) - c \right] + \sum_{\omega \in R} \omega \left[ \sigma_2 (1 - x_2, 2) - c \right] - K
\]

\[
+ \sum_{\omega \in \{h,l\} \setminus R} \omega \left[ Q_U \rho_{\omega} x_1 \left[ 1 - 2x_2, 2 - \rho_{\omega} x_1 \right] + x_2, 2 \left[ Q_1 (1 - x_2) - c \right] \right].
\]

The derivative of this expression with respect to \( Q_U \) is,

\[
\frac{d\Pi_R}{dQ_U} = \sum_{\omega \in \{h,l\} \setminus R} \omega \rho_{\omega} x_1 \left[ 1 - 2x_2, 2 - \rho_{\omega} x_1 \right]. \tag{23}
\]

Evaluating this expression at \( Q_U = 0 \) we get \( \omega \rho_{\omega} x_1 \left[ 1 - \frac{Q_1 - c}{Q_1} - \rho_{\omega} \frac{\sigma_2 - c}{2\sigma_1} \right] = \omega \rho_{\omega} x_1 \left[ c \left( \frac{\sigma_1 + \rho_{\omega} Q_1}{Q_1 \sigma_1} \right) - \rho_{\omega} \right]. \]

if \( c < \frac{\rho_{\omega} Q_1 \sigma_1}{2(\sigma_1 + \rho_{\omega} Q_1)} \) then this derivative is less than zero. If the quality of new un revised book and the revised book are the same and \( Q_U = 0 \) then the optimum quantities for all revision plans are
the same. Profits are also the same after revision costs. Keeping the revision choice for the other state constant suppose that the derivative of the profit in the no revision case is less than zero. Since this is a continuous differentiable function then there exists some positive range of possible $Q_U$ where the profits to revise in state $\omega$ are higher. In this range the monopolist is willing to pay a positive revision cost to produce a book of the same quality as the un revised book.

\section*{Proof. of Lemma 1}

1) Recall that if the books are not revised the second period used book price is, $P_{\omega,u}(x_1, x_{\omega,2}; R) = Q_U(1 - x_{\omega,2} - \rho_\omega x_1)$. From the first order condition for the second period output choice $x_{\omega,2} = \frac{1}{2} - \frac{c}{2Q_U} - \rho_\omega x_1$. Substituting in this into the price we get the used price $P_{\omega,u} = Q_U(\frac{1}{2} + \frac{c}{2Q_1})$ which is the same for all states $\omega$ and therefore all possible stocks of used books.

2) The 2nd period new book price is, $P_{\omega,2}(x_1, x_{\omega,2}; R) = (Q_1 - Q_U)(1 - x_{\omega,2}) + Q_U(1 - x_{\omega,2} - \rho_\omega x_1)$. Substituting the $x_{\omega,2}$ first order condition, the second period new book price is, $P_{\omega,2} = Q_1(\frac{1}{2} + \frac{c}{2Q_1}) + (Q_1 - Q_U)\rho_\omega x_1$. This is increasing with $\rho_\omega$ if and only if used and new books are not perfect substitutes (i.e. $Q_1 > Q_U$). Otherwise if new and used books are perfect substitutes, (i.e. $Q_1 = Q_U$), the stock of used books does not affect new book price.

\section*{Proof. of Proposition 6.} Given a first period production $x_1$, the second period profits in state $\omega$ if they revise,

$$\Pi^r = \frac{(Q_2 - c)^2}{4Q_2} - K$$

And the profits if they do not revise are,

$$\Pi^{nr} = \max_{x_{\omega,2}} (Q_1 (1 - x_{\omega,2}) - \rho_\omega Q_U x_1 - c) x_{\omega,2} = \frac{(Q_1 - \rho_\omega Q_U x_1 - c)^2}{4Q_1}$$

Since $\rho_h > \rho_l$ this profit will be smaller in state $h$. Therefore, if the publisher updates in state $l$ it must also update in state $h$. 

32
The publisher will only revise in state h if

\[
\frac{(Q_1 - \rho_l Q_U \hat{x}_1 - c)^2}{4Q_1} \geq \frac{(Q_2 - c)^2}{4Q_2} - K \geq \frac{(Q_1 - \rho_h Q_U \hat{x}_1 - c)^2}{4Q_1}
\]

\[
\rho_l \hat{x}_1 \leq \frac{1}{Q_U} \left( Q_1 - c + \sqrt{4Q_1 \left( \frac{(Q_2 - c)^2}{4Q_2} - K \right)} \right) \leq \rho_h \hat{x}_1
\]

Now I will show that the publisher will never need to commit itself to not revise in any state. If the publisher does not want to revise in state \( l \) and chooses to produce \( x_1^* \) in period 1 then

\[
\frac{(Q_1 - c)^2}{4Q_1} + \frac{Q_U}{Q_1} \rho_{\omega} x_1^* \left[ c - \rho_{\omega} x_1^* \left( Q_1 - \frac{3}{4} Q_U \right) \right] = \frac{(Q_1 - \rho_{\omega} Q_U \hat{x}_1 - c)^2}{4Q_1} + \frac{-\rho_{\omega} Q_U \hat{x}_1 \left( Q_1 - c + \rho_{\omega} Q_U \hat{x}_1 \left( 2 \frac{Q_1}{Q_U} - 1 \right) \right)}{2Q_1}
\]

\[
\geq \frac{(Q_1 - c)^2}{4Q_1} - K
\]

Since \( \frac{-\rho_{\omega} Q_U \hat{x}_1 \left( Q_1 - c + \rho_{\omega} Q_U \hat{x}_1 \left( 2 \frac{Q_1}{Q_U} - 1 \right) \right)}{2Q_1} \leq 0 \) This condition is stronger than the condition to revise in state \( \omega \)

\[
\frac{(Q_1 - \rho_{\omega} Q_U \hat{x}_1 - c)^2}{4Q_1} \geq \frac{(Q_1 - c)^2}{4Q_1} - K
\]

Therefore the publisher would never choose an \( \hat{x}_1 \) to commit itself to not revise. The publisher will only revise in state h if

\[
\frac{(Q_1 - \rho_l Q_U \hat{x}_1 - c)^2}{4Q_1} \geq \frac{(Q_2 - c)^2}{4Q_2} - K \geq \frac{(Q_1 - \rho_h Q_U \hat{x}_1 - c)^2}{4Q_1}
\]

\[
\rho_l \hat{x}_1 \leq \frac{1}{Q_U} \left( Q_1 - c + \sqrt{4Q_1 \left( \frac{(Q_2 - c)^2}{4Q_2} - K \right)} \right) \leq \rho_h \hat{x}_1
\]

If the publisher chooses \( \hat{x} \) to commit itself to revise in state \( h \) then \( \frac{(Q_2 - c)^2}{4Q_2} - K = \frac{(Q_1 - \rho_{\omega} Q_U \hat{x}_1 - c)^2}{4Q_1} \)

Therefore \( \frac{(Q_1 - \rho_{\omega} Q_U \hat{x}_1 - c)^2}{4Q_1} \geq \frac{(Q_2 - c)^2}{4Q_2} - K \) and it will not revise in state \( l \).

Now I will provide conditions where the publisher will only revise in state \( h \). Given that the
firm can commit to the revision decision \( R \).

\[
x_1 = \frac{Q' - c + \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \frac{Q_U}{Q_1} \rho_{\omega} c}{2 \left( Q' + \frac{Q_U}{Q_1} (Q_1 - \frac{3}{4} Q_U) \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \rho_{\omega}^2 \right)} \geq \frac{Q' - c}{2 [Q' + Q_U]}
\]

We can choose parameter values such that \( \frac{(Q_2-c)^2}{4Q_2} - K = \varepsilon \geq \left( \frac{Q_1 - \rho_q Q_U \left( \frac{Q' - c}{2 [Q' + Q_U]} \right) - c}{4Q_1} \right)^2 \Rightarrow \frac{(Q_2-c)^2}{4Q_2} - K = \varepsilon \). In this case the publisher would only revise in state \( h \).

We can show that

\[
\frac{(Q_1 - c)^2}{4Q_1} + \frac{Q_U}{Q_1} \rho_q \bar{x}_1 \left[ c - \rho_q \bar{x}_1 \left( Q_1 - \frac{3}{4} Q_U \right) \right] = \frac{(Q_1 - \rho_q Q_U \bar{x}_1 - c)^2}{4Q_1} + \frac{-\rho_q Q_U \bar{x}_1 \left( Q_1 - c + \rho_q Q_U \bar{x}_1 \left( 2 \frac{Q_1}{Q_U} - 1 \right) \right)}{2Q_1} \leq \frac{(Q_1 - \rho_q Q_U \bar{x}_1 - c)^2}{4Q_1}
\]

Therefore some sufficient conditions for only revising in \( h \) are \( \frac{(Q_1 - \rho_q Q_U \bar{x}_1 - c)^2}{4Q_1} \geq \frac{(Q_2-c)^2}{4Q_2} - K \geq \left( \frac{Q_1 - \rho_q Q_U \left( \frac{Q' - c}{2 [Q' + Q_U]} \right) - c}{4Q_1} \right)^2 \).

**Proof.** of Proposition 7. The second period firm will revise the book if \( \frac{(Q_1 - \rho_q Q_U \bar{x}_1 - c)^2}{4Q_1} \leq \frac{(Q_2-c)^2}{4Q_2} - K \).

\[
x_1 = \frac{Q' - c + \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \frac{Q_U}{Q_1} \rho_{\omega} c}{2 \left( Q' + \frac{Q_U}{Q_1} (Q_1 - \frac{3}{4} Q_U) \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \rho_{\omega}^2 \right)} \geq \frac{Q' - c}{2 [Q' + Q_U]}
\]

\( \Rightarrow \frac{(Q_1 - \rho_q Q_U \bar{x}_1 - c)^2}{4Q_1} < \left( \frac{Q_1 - \rho_q Q_U \left( \frac{Q' - c}{2 [Q' + Q_U]} \right) - c}{4Q_1} \right)^2 \leq \frac{(Q_1 - c)^2}{4Q_1} - K \). Therefore the firm will always update in this state. ■

**Proof.** Of Proposition 4 We will now show that given a revision decision by the firm, profits are
increasing with the used book quality \( Q_U \) on the interval \( (\frac{1}{2}Q_1, Q_1) \). Given the revision decision \( R \) the profit for the firm is,

\[
\Pi_R = \max_{x_1, x_{1,2}} x_1 [\sigma_1(1 - x_1) - c] + \sum_{\omega \in R} q_\omega \left( x_{\omega,2} [Q_2(1 - x_{\omega,2}) - c] - K \right) + \sum_{\omega \in \{h,l\}\backslash R} q_\omega \left( Q_U \rho_\omega x_1 [1 - 2x_{\omega,2} - \rho_\omega x_1] + x_{\omega,2} [Q_1(1 - x_{\omega,2}) - c] \right).
\]

(24)

Using the envelope theorem the derivative of this expression with respect to \( Q_U \) is,

\[
\frac{d\Pi_R}{dQ_U} = \sum_{\omega \in \{h,l\}\backslash R} q_\omega \left( \rho_\omega x_1^* \left[ 1 - 2x_{\omega,2}^* - \rho_\omega x_1^* \right] \right).
\]

(25)

Where \( x_{\omega,2}^* \) and \( x_1^* \) are the optimal production values. From the FOC on \( x_{\omega,2}^* = \frac{1}{2} - \frac{c}{2Q_1} - Q_U \rho_\omega x_1^* \). Substituting this into the above equation we get

\[
\frac{d\Pi_R}{dQ_U} = \sum_{\omega \in \{h,l\}\backslash R} q_\omega \left( \rho_\omega x_1^* \left[ \frac{c}{Q_1} - \rho_\omega x_1^* \left( 1 - \frac{2Q_U}{Q_1} \right) \right] \right).
\]

(26)

We will now show that the firm can never increase profits by reducing quality. We will show this by contradiction. Suppose that the publisher could increase profits by reducing \( Q_U \). We know from Proposition 1 that profits are lower if the firm reduces used book quality to zero. By the envelope theorem \( \frac{dn_R}{dQ_U} = \sum_{\omega \in \{h,l\}\backslash R} q_\omega \left( \rho_\omega x_1^* \left[ \frac{c}{Q_1} - \rho_\omega x_1^* \left( 1 - \frac{2Q_U}{Q_1} \right) \right] \right) \). Note, this must be positive when \( Q_U > \frac{1}{2}Q_1 \). If \( \Pi_R \) is maximized for some \( Q_U \in (0, \frac{1}{2}) \) then \( \frac{dn_R}{dQ_U} = 0 \) must have at least two solutions. Suppose that there were more than one solution \( \sum_{\omega \in \{h,l\}\backslash R} q_\omega \rho_\omega \left[ \frac{c}{Q_1} - \rho_\omega x_1^* \left( 1 - \frac{2Q_U}{Q_1} \right) \right] = 0 \) and \( \frac{dx_1^*}{dQ_U} = \frac{1}{2Q_U + \sum_{\omega \in \{h,l\}\backslash R} q_\omega \rho_\omega} \left[ \sum_{\omega \in \{h,l\}\backslash R} q_\omega \rho_\omega \left( \frac{c}{Q_1} - 2\rho_\omega x_1^* \left( 1 - \frac{2Q_U}{Q_1} \right) \right) \right] \Rightarrow x_1^* \) is decreasing with \( Q_U \) at this point \( (Q'_U) \). Therefore there exists a range of qualities \( >Q'_U \) for which \( \frac{dn_R}{dQ_U} > 0 \) and another range of values \( < Q'_U \) where \( \frac{dn_R}{dQ_U} > 0 \). Therefore any two solutions to this equality will need have a positive distance between them. Take \( Q'_U < Q'_{U} < 1/2 \) where \( Q'_U \) and \( Q''_U \) are the two smallest solutions to the equality. If they solve the equality that solve this \( x_1^*(Q'_U) < x_1^*(Q''_U) \) therefore \( x_1^*(Q) \) must be increasing somewhere on this range. Therefore by the intermediate value theorem there must be a solution to \( \frac{d\Pi_R}{dQ_U} = 0 \) in the range \( (Q'_U, Q''_U) \) therefore we have a contradiction.

\textbf{Proof.} Of Proposition 5. For any revision choice, the solution of the maximization problem is
continuously differentiable. Suppose that \( c < \frac{\rho_\omega Q_1 Q'}{2Q' + \frac{Q'}{2} + \rho_\omega Q_1} \) for \( \omega = h, l \Rightarrow \frac{c}{Q_1} < \rho_\omega \frac{Q' - c}{2Q' + \frac{Q'}{2}} \leq \rho_\omega \frac{Q' - c + \sum_{\omega \in \{h,l\}\setminus R} q_\omega \frac{Q_1}{Q_1} \rho_\omega c}{2Q' + \frac{Q'}{2} + \rho_\omega Q_1} = \rho_\omega x_1 \). Therefore the derivative \( \frac{d\Pi_R}{dQ_U} \bigg|_{Q_U=0} < 0 \). Since \( \Pi_R \) is continuously differentiable then \( \frac{d\Pi_R}{dQ_U} \) will be decreasing in \( Q_U \) in some neighborhood around zero.

If the initial used quality is within this neighborhood the firm can increase profits by reducing quality.

**Proof.** Of Corollary 2. recall, \( x_1^* = \frac{Q' - c + \sum_{\omega \in \{h, l\}\setminus R} q_\omega \frac{Q_U}{Q_1} \rho_\omega c}{2Q' + \frac{Q_U}{Q_1} (Q_1 - Q_U) \sum_{\omega \in \{h, l\}\setminus R} q_\omega \rho_\omega^2} \)

\[
\frac{dx_1^*}{dQ_U} = \frac{1}{2Q' + \frac{Q_U}{Q_1} (Q_1 - Q_U) \sum_{\omega \in \{h, l\}\setminus R} q_\omega \rho_\omega} \left[ \frac{\sum_{\omega \in \{h, l\}\setminus R} q_\omega \rho_\omega \left( \frac{c}{Q_1} - \rho_\omega x_1^* \left( 1 - \frac{2Q_U}{Q_1} \right) \right)}{2Q' + \frac{Q_U}{Q_1} (Q_1 - Q_U) \sum_{\omega \in \{h, l\}\setminus R} q_\omega \rho_\omega^2} \right] \]

If \( \frac{d\Pi_R}{dQ_U} < 0 \Rightarrow \sum_{\omega \in \{h, l\}\setminus R} q_\omega \rho_\omega \left( \frac{c}{Q_1} - \rho_\omega x_1^* \left( 1 - \frac{2Q_U}{Q_1} \right) \right) < 0, \) \( Q_U < \frac{Q_1}{2} \) therefore \( \frac{dx_1^*}{dQ_U} < 0 \).

Now \( Q_U x_1^* = \frac{Q' - c + \sum_{\omega \in \{h, l\}\setminus R} q_\omega \frac{Q_U}{Q_1} \rho_\omega c}{2Q' + \left( 1 - \frac{Q_U}{Q_1} \right) \sum_{\omega \in \{h, l\}\setminus R} q_\omega \rho_\omega^2} \) as \( Q_U \) decreases \( Q_U x_1^* \) decreases and \( x_2 \) increases. This is a different empirical prediction for quantity of books sold.

**Proof.** Of Proposition 8. We will now show that given a revision decision by the firm, profits are increasing with the used book quality \( Q_U \) on the interval \((\frac{2}{3}Q_1, Q_1)\). Given first period production and the second period revision decision. If the firm does not revise in that state, The second period publisher will choose \( x_{\omega, 2} \) to solve

\[
\max_{x_{\omega, 2}} x_{\omega, 2} \left[ Q_1 (1 - x_{\omega, 2}) - Q_U \rho_\omega x_1 - c \right]
\]

Let us denote the solution to this as \( \Pi_{2, \omega}(x_1, Q_U) \). The first order condition on the choice of \( x_{\omega, 2}^* = \frac{1}{2} - \frac{c}{2Q_1} - \left( \frac{Q_U}{2Q_1} \right) \rho_\omega x_1^* \). Given the revision decision \( R \) the profit for the firm is,

\[
\Pi_R(x_1) = x_1 \left[ \sigma_1 (1 - x_1) - c \right] + \sum_{\omega \in \{h, l\}\setminus R} q_\omega \left( Q_U \rho_\omega x_1 \left[ \frac{1}{2} + \frac{c}{2Q_1} - \rho_\omega x_1 \left( 1 - \frac{Q_U}{2Q_1} \right) \right] \right) + \Pi_{2, \omega}(x_1, Q_U) + \sum_{\omega \in R} q_\omega \left( \frac{(Q_2 - c)^2}{4Q_2} - K \right) .
\]

(28)
Using the envelope theorem the derivative of this expression with respect to $Q_U$ is,

$$
\frac{d\bar{\Pi}_R}{dQ_U} = \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \left( \rho_{\omega} x_1^* \left[ \frac{1}{2} + \frac{c}{2Q_1} - \rho_{\omega} x_1^* \left( 1 - \frac{Q_U}{Q_1} \right) \right] \right) - \rho_{\omega} x_1^* x_{\omega,2}.
$$

(29)

$$
\frac{d\bar{\Pi}_R}{dQ_U} = \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \left( \rho_{\omega} x_1^* \left[ \frac{c}{Q_1} - \rho_{\omega} x_1^* \left( 1 - \frac{3Q_U}{2Q_1} \right) \right] \right).
$$

(30)

This is greater than zero whenever $Q_U > \frac{2}{3} Q_1$. Therefore if the publisher were to reduce used book quality away from $Q_1$ to any value above $\frac{2}{3} Q_1$ this would reduce profitability. ■

Proof. of Proposition 9. As determined in the proof of Proposition 8. The derivative of the profit function with respect to $Q_U$ given a fixed revision decision is positive. Therefore without changing the revision, decision decreasing $Q_U$ must decrease profits. However decreasing $Q_U$ will relax the second period revision decision. Let us look at the optimal first period production decision as we decrease $Q_U$. Since note that the cutoff value $M_\omega = Q_U x_1^*$ and $x_{\omega,2}$ does not change with $Q_U$. Therefore the maximum profit can now be denoted as,

$$
\bar{\Pi}(x_1^*) = x_1^* [\sigma_1 (1 - x_1^*) - c] + \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \left( \rho_{\omega} M_\omega \left[ 1 - x_{\omega,2} - \rho_{\omega} x_1^* \right] + \frac{(Q_1 - \rho_{\omega} M_\omega - c)^2}{4Q_1} \right),
$$

(31)

$$
+ \sum_{\omega \in R} q \left( \frac{(Q_U - c)^2}{4Q_2} - K \right).
$$

(32)

Derivative WRT $Q_U$

$$
\frac{d\bar{\Pi}(x_1^*)}{dQ_U} = \left[ \sigma_1 (1 - 2x_1^*) - c \right] - \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} (\rho_{\omega})^2 M_\omega \frac{dx_1^*}{dQ_U}
$$

(33)

Since $\frac{dx_1^*}{dQ_U} < 0$, $\frac{d\bar{\Pi}(x_1^*)}{dQ_U} < 0$ whenever,

$$
[\sigma_1 (1 - 2x_1^*) - c] - Q_U x_1 \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} (\rho_{\omega})^2 > 0.
$$

(34)

Which happens whenever $M_\omega < \frac{\sigma_1 - c}{2 \left( \frac{x_1^*}{Q_1} + \frac{1}{z} \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} (\rho_{\omega})^2 \right)}$. This is 1) on Condition ??.

Proof. of Lemma 2

1)Recall that if the books are not revised the second period used book price is, $P_{\omega,u}(x_1, x_{\omega,2}, R) =$
\[ Q_U(1 - x_{\omega,2} - \rho_\omega x_1). \] From the first order condition for the second period output choice \( x_{\omega,2} = \frac{1}{2} - \frac{c}{2Q_1} - \frac{\rho_\omega x_1}{2} \). Substituting in this into the price we get the used price \( P_{\omega,u} = Q_U(\frac{1}{2} + \frac{c}{2Q_1} - \frac{\rho_\omega x_1}{2}) \) which is negatively related to the number of used books in the market.

2) The 2nd period new book price is, \( P_{\omega,2}(x_1, x_{\omega,2}, R) = (Q_1 - Q_U)(1 - x_{\omega,2}) + Q_U(1 - x_{\omega,2} - \rho_\omega x_1). \) Substituting the \( x_{\omega,2} \) first order condition, the second period new book price is, \( P_{\omega,2} = Q_1(\frac{1}{2} + \frac{c}{2Q_1}) + \left(\frac{Q_1}{2} - Q_U\right) \rho_\omega x_1. \) This is decreasing with the stock of used books \((\rho_\omega x_1)\) whenever (i.e. \( Q_U > \frac{Q_1}{2} \)).

**Proof.** of Proposition 10. Reselling previously leased books essentially allows the publisher to sell a lower quality book at zero cost. Suppose that the publisher can sell an unlimited amount of both quality types. The used book costs \( c \) to print and the used book costs 0. The publisher in the second period would choose high and low quantities \((x_h \text{ and } x_l \text{ respectively})\) to maximize,

\[ \Pi_2 = \left( Q_U x_l \left[ 1 - 2x_h - x_l \right] + x_h \left[ Q_1 (1 - x_h) - c \right] \right). \]

This is equivalent to the profits made on the second period of the initial problem including the resale of the first period books. The FOC on \( x_h \) is \( Q_1 - 2Q_1 x_h - 2Q_U x_l - c = 0 \). The FOC on \( x_l \) is \( Q_U [1 - 2x_h - 2x_l] = 0 \). Since \( Q_1 > Q_U > 0 \) This function is concave. Combining the two FOC gives the optimal production of \( x_l = \frac{c}{2(Q_1 - Q_U)}. \) We can then compare this to the quantity of used books sold without leasing. In the non leasing model if the publisher does not revise in the second period and the state of the world is \( \omega \) then the stock of used books is, \( \rho_\omega x_1 = \frac{Q' - c + \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \frac{Q_U}{Q_1} \rho_\omega c}{2 \left[ Q' + \frac{Q_U}{Q_1} (Q_1 - Q_U) \right] \sum_{\omega \in \{h,l\} \setminus R} q_{\omega} \rho_{\omega}^2} \rho_\omega. \) If there is a state of the world that this is greater than \( x_l = \frac{c}{2(Q_1 - Q_U)} \), the publisher would prefer to lease at least part of the books in order to reduce second period output.

**References**


