An Empirical Analysis of Planned Obsolescence

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This paper examines the decision to introduce new products by durable goods producers. Conventional wisdom suggests that durable goods producers introduce new products to kill off used products. However, used units may not compete with new units if initial price can capture the present value of all future transactions. Using new data from the textbook market, I find that publishers revise editions more frequently when competition from used textbooks increases. This suggests the presence of planned obsolescence. However, the time since the previous revision also significantly affects revision decisions, indicating that publishers' frequent revision cannot be attributed to planned obsolescence alone.

1. Introduction

Durable goods producers face potential competition from used units because of the long-lasting nature of the products. To avoid such competition, firms may "kill off" used units by introducing a new version of the product, which makes the used units economically obsolete. Such behavior is referred to "planned obsolescence." Often cited examples include auto manufacturers and textbook publishers, both of which periodically introduce new products. On the other hand, economists have suggested the possibility that used units may not compete with new units because the price of new goods reflects the present value of all future services of a product (e.g., Swan, 1980).[1] This suggests that manufacturers may not have an incentive to kill off used units under some specific conditions. In such cases, periodic introductions of new

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1. This requires the assumption that used and new units are perfect substitutes. As I discuss later, however, the perfect substitutability assumption would not hold in the textbook market.

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models may be motivated by other reasons. For example, firms may need to introduce new products periodically, because, otherwise, the demand for their products may decline as technology and/or information content becomes outdated. Alternatively, the frequency of new product introduction may be influenced by the extent of competition that the product faces from alternative new products within the same market.

In contrast to a large theoretical literature on planned obsolescence, empirical examination on the same has been very limited. This is primarily due to a lack of data on used markets. Using a new data set containing information on new and used textbook transactions, this paper attempts to fill this gap by examining the extent to which textbook publishers introduce new editions to kill off used units. The textbook publishing market is ideal for examining planned obsolescence due to the following reasons. First, as often appear in the popular press, conventional views suggest that textbook publishers periodically introduce new editions to kill-off used textbooks.[2] Second, it is reasonable to treat used textbooks of the same title-edition as homogeneous, which substantially reduces the dimensionality of the analysis.[3] The same treatment would be difficult, say, for used cars where prices for the same model year would vary substantially depending on the condition of the vehicle.[4] Third, and more important, new data on the used textbook market has become available recently.

The data for this study are collected from college bookstores, containing semi-annual textbook-level data for 1996–2000. For this study, I examined only data on textbooks used in economics courses. Approximately 2,500 observations are included in the estimation. For each period, I observe, among other variables, average retail prices (new vs. used), quantity sold (new vs. used), ISBN, and the edition revision information.

Empirically, I analyze the revision decisions of textbook publishers using reduced-form, discrete-time duration models with time-varying covariates. I construct a variable that captures the extent of competition between used and new units and examine how this affects the timing of textbook revision. Various product and market attributes including the age of the textbook, textbook categories, physical characteristics of

2. See, for example, a recent article by Erwin V. Cohen, "Same Book, New Look," *The Wall Street Journal*, December 3, 2003.

3. The assumption is reasonable because used textbooks of the same edition are commonly sold at the same price regardless of their exact conditions. Part of the reason for this is college bookstores do not buy back used textbooks in poor condition.

4. See Esteban and Shum (2005) for more discussion.

the textbook, market size, and rival firm's revision decision are also included in the estimation. A split-population model that accounts for unobserved individual heterogeneity is also estimated.

I found that, at the aggregate level, textbook publishers introduce new textbooks more frequently when the share of used textbooks increases, holding all other factors constant. This result is consistent with the view that publishers introduce new editions to kill off used units. Point estimate suggests that if the used textbook share increases from zero to one, hazard rate increases more than three times. I also find that the time elapsed since the introduction of the current edition is also an important determinant of textbook revision. In contrast, regarding the competition among the textbooks in the same category, I did not find the evidence that the rival firm's revision decision increases the likelihood of revising own textbook. These results are robust to various specifications.

Interestingly, however, these results were not identical across textbook subcategories. In particular, accumulation of used books has little impact on the hazard rate of "principles" textbooks, while the same factor is important in the "applied" category. In contrast, the time since previous revision has a much larger impact on the hazard rate in the "principles" category than in the "applied" category. Thus, although the time alone can well explain the publisher's revision decision in the "principles" category, competition from used units is an important determinant of textbook revision in the "applied" category.

To my knowledge, this is the first paper that empirically examines the durable goods producer's decision to introduce new models when facing competition from used units. However, several empirical papers are related to the current paper. Porter and Sattler (1999) construct a model in which heterogeneous consumers specialize in different types of used automobiles and show that the patterns of trade are consistent with their model but not with that of adverse selection. Esteban and Shum (2005) constructed a dynamic structural model to examine the effects of durability and secondary markets on equilibrium firm behavior in the automobile market. Purohit (1992) examined how the prices for used cars are affected by the introduction of new models and found that old car prices fall when new models are introduced. Suslow (1986) examined whether competition from the recycling sector affected the market power of a monopolist in the primary sector, using Alcoa as an example. Although these papers are related to the current paper, they do not address durable goods producers' decisions to introduce new products to avoid potential competition from used units, the main objective of this paper.

A recent study by Greenstein and Wade (1998) is also related to the current paper. They examined the determinants of exit and entry of models in the commercial mainframe computer market. Using duration models similar to this paper, they find, among other things, that the degree of competition, firm attributes, and vintage of product affect firms' exit and entry decisions. Their paper, however, does not address how competition from used units affects the decision to introduce new models.

The rest of the paper is organized as follows. Section 2 briefly reviews related literature. Section 3 describes the data set. Section 4 discusses theoretical underpinnings and the empirical model. Estimation issues are discussed in Section 5. Section 6 reports results and the following section concludes the paper.

2. A Brief Review of Literature

Two streams of theoretical literature on durable goods monopolist are relevant to this paper.[5] The first group has concerned with the choice of durability by a monopoly seller. In particular, authors have examined whether durable goods producers, faced with potential competition from used units, reduce durability of a product below the socially-optimal level. This includes, for example, Swan (1970, 1972), Bulow (1982), Rust (1986), and Waldman (1996a). Swan shows that, under some model assumptions, the monopolist has no incentive to reduce durability below the socially optimal level. Rust (1986), however, shows that this well known "independence result" does not hold if one relaxes Swan's assumptions, such as that new and used durables are perfect substitutes and that the lifetime distribution of a durable is exogenously determined and inalterable once fixed at the date of production. Similarly, by relaxing Swan's assumption that producers commit to a once and for all choice of price and durability, Bulow (1982, 1986) show that the monopolist has an incentive to reduce durability below the socially optimal level.

Instead of reducing the durability of their products, durable goods producers may periodically introduce new models and "kill off" used units. This behavior of durable goods producers is called planned obsolescence, and this is the main focus of this paper.[6] The second group of authors, including Miller (1974), Benjamin and Kormendi (1974), Waldman (1993), and Fishman and Rob (2000), have examined

5. See Waldman (2003) for a broad overview of the durable goods literature.

6. Rust (1986) provides more discussion on the difference between "reducing durability" and "planned obsolescence."

theoretical models of planned obsolescence. Among these authors, two distinctive views exist on firms' product introduction decisions. On the one hand, it has been argued that the price for a new product incorporates all future transactions, and thus used units do not compete with new units. For example, Swan (1980) argues:

> . . . [T]he pure monopolist 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 and recyclers in the case of aluminum) can then buy and sell the item indefinitely without in any way restricting the power of the monopolist as the original seller (p. 78).

The above discussion suggests that durable goods producers may not have an incentive to "kill off" used units under some conditions. In this case, periodic introductions of a new model are not due to planned obsolescence, and it should be explained by other factors. For example, the demand for the durable good may decline over time as the product becomes obsolete, and this may trigger the introduction of a new model.

On the other hand, others have argued that durable goods producers are motivated to eliminate the secondhand goods market in order to increase their profits. Earlier theoretical papers partially support this view. For example, Benjamin and Kormendi (1974) find that, under certain conditions, a monopolist can increase profitability by eliminating the used goods market, but this relation can be reversed under other conditions. Similarly, Miller (1974) specifically examines the textbook market and find that a monopolist may or may not increase profits by killing off the secondhand market. More recently, Waldman (1993) shows that, in the presence of network externality, a monopolist faces "too high" an incentive to introduce a technology in the second period that is not compatible with the product sold during period one. This happens because the seller does not internalize the loss of values for the previously sold units due to the introduction of new goods.

In sum, existing theory models suggest that, under some model assumptions and parameter values, planned obsolescence can be optimal.[7] In the following, I empirically examine whether textbook publishers engage in planned obsolescence, and if so, to what extent the phenomenon

7. Other theoretical papers on durable goods producers include Choi (1994), Waldman (1996b), and Fudenberg and Tirole (1998).

is important in the textbook market. Now I turn to the discussion of the data used in the analysis.

3. Data

3.1 Describing the Data

The data used in this study are collected from college bookstores. For each semester, Monument Information Resource (MIR) collects information on the number of textbooks sold (new vs. used), average prices (new vs. used), edition number, year and month of publication, author name, textbook categories, publisher name, and the ISBN code. For this study, I use only economics textbooks that appear in the MIR database between 1996 and 2000. MIR collects data twice a year, and this gives me at most ten semesters' observations for each textbook.[8] I refer to these semesters as fall and spring semesters. MIR estimates that their data cover approximately 46% of the total college textbook market in the United States in 2000.[9] Physical characteristics of textbooks, such as number of pages, color illustration, and size of textbook, are collected from the Library of Congress web site, Amazon.com, and Barnesandnoble.com using the ISBN code.

The main limitation of the data is that the MIR data cover only the transactions that take place through college bookstores. For example, buying and selling textbooks through online bookstores are not captured in the data. The data period I examine (i.e., 1996–2000) is fortunate, however, that the online sales of textbooks appears to be relatively small. According to the estimate by National Association of College Stores, online textbook sales accounts for only 7% as late as in 2002. Nonetheless, the results should be viewed with care since the data also do not contain other transactions such as the transactions between the students.

For the ten semesters between 1996 and 2000, I have a total of 2,561 observations. An observation is a title–edition–semester. It is common for publishers to revise textbook editions over time, using almost identical names for the textbooks. A "title" refers to the name of a textbook. There are 405 unique textbook titles in the data set. On average, each title has 1.7 editions in the data set, and I observe a total of 292 edition revisions or "failures." Because of the relatively short panel, many title-editions are either right censored or delayed entry (or left

8. The textbook sales during summer are combined with the spring sessions. Ideally, one would like to observe the "summer" period separately from the spring semester. Unfortunately, MIR does not collect data separately for spring and summer sessions.

9. MIR's data coverage increased between 1996 and 2000. I used these coverage rates to recover the number of total used and new textbooks sold for each title in each semester.

truncated). I will discuss how I deal with these issues in the estimation section. Study guides, custom textbooks, government publications, and Canadian editions were excluded from the analysis.[10]

When multiple ISBNs for the same title-edition are observed in one semester, these observations are aggregated up to the title-edition.[11] The multiple ISBNs per edition typically happens with textbook "packages," in which textbooks are bundled with additional materials, such as a study guide, CD-Rom, and *The Wall Street Journal*.[12] It is necessary to combine these textbooks because textbooks originally sold as part of packages may be sold as a stand-alone textbook in the used textbook market. Combining all observations of the same title-edition allows me to compare the quantity of used and new units sold over time. However, because the timing of new product introduction may also depend on whether the textbook is bundled, I control for this by including a dummy variable that indicates the existence of a package edition. The results change little due to this addition.[13]

In order to analyze the revision decision of the textbook publisher, one has to define the timing of a revision. I identify the entry of a new edition when I observe a new edition of a textbook in the MIR data. For those textbooks introduced before spring 1996, the month of the new edition entry was identified using the MIR data, Amazon.com, and Barnesandnoble.com. I also searched the latter two databases to find out whether a new edition of a title was introduced immediately after the fall 2000 semester, when my data set is truncated.[14] Sometimes an old edition of a title is sold even after a new edition of the same title is introduced. I dropped these "overlapping" observations when analyzing the publisher's decision to revise editions.

Figure 1 shows the pattern of edition revisions and the quantity share of new textbooks in two textbook categories. Panel A and B presents selected textbooks in the Macroeconomics-Principles and Advanced Microeconomics categories, respectively. The four textbooks in

10. I do not include study guides because their revision decisions are primarily determined by the revision decisions of accompanied textbooks. Custom textbooks usually do not have used markets, and thus are excluded. Canadian editions of a textbook were not included. I do not observe many of these editions because MIR does not cover much of the Canadian market.

11. Different ISBN codes are assigned not only for different editions of the same title, but also for different packages of the same edition.

12. For example, Mankiw's *Principles of Economics* has more than five different packages for its second edition sold in spring 2000.

13. The results are essentially identical with or without the dummy variable, and thus, in Section 6, I report the results without including the dummy variable. The results that contain the dummy variable are available from the author.

14. That is, if a new edition was introduced in spring 2001, I code revision decision = 1 for fall 2000 (discussed in detail below).

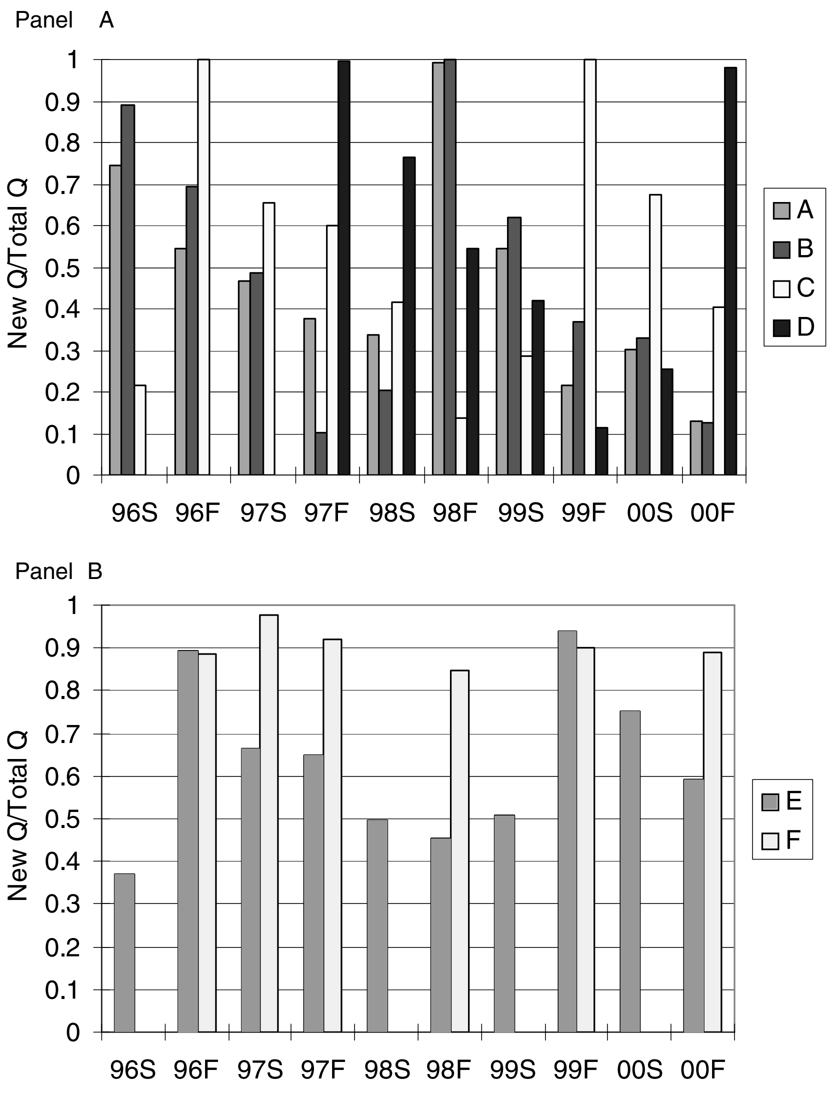

FIGURE 1. PANEL A: PERCENT OF TEXTBOOKS SOLD—NEW VERSUS USED: SELECTED MACROECONOMICS-PRINCIPLES TITLES. PANEL B: PERCENT OF TEXTBOOKS SOLD—NEW VERSUS USED: SELECTED ADVANCED MICROECONOMICS TITLES

Panel A show a remarkably similar pattern: following the introduction of a new edition, the share of new textbooks decreases to 60–70% in the next semester. The share continues to decrease up to 10–20% afterwards, and a new edition is introduced after five or six semesters, when the

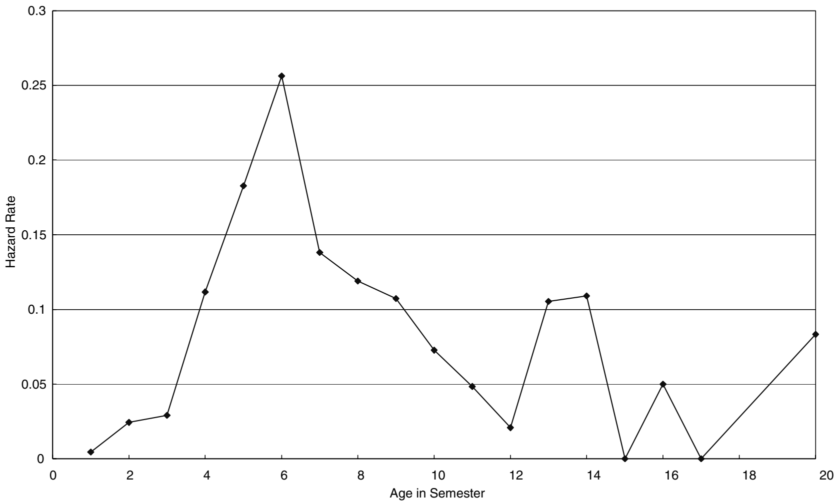

FIGURE 2. LIFE TABLE ESTIMATOR: HAZARD RATES (TRUNCATED AT SEMESTER AGE = 20)

market share for new textbooks goes back to approximately 100%.[15] Panel B shows a slightly different pattern. For example, the share of new textbooks for title "F" continues to be large during the sample period, and in fact the publisher did not revise the edition throughout the period.[16] In contrast, the new textbook share for title "E" decreases over time and a new edition was introduced in fall 1999. These patterns suggest that the share of used textbooks may indeed be an important factor based on which the publisher decides when to introduce a new edition of the textbook.

Figure 2 shows the hazard rate using the life table estimators, pooling all observations in the data set. A unit of observation is textbook–title–edition.[17] The x-axis of Figure 2 is truncated at 20, in order to show more detail in lower age range, which is where most of action is. The figure indicates that many textbook editions complete their publication

15. The first edition of title "D" was published in fall 1997. Thus there are no data for "D" prior to fall 1997.

16. The first edition of title "F" was published in fall 1996. Thus there are no data for "F" prior to the semester. Also, the textbook "F" is typically used in the fall semester, and thus there is no data for "98S," "99S," and "00S."

17. That is, if there is more than one edition of the same title, all editions are included in constructing the estimator. Alternatively, one can construct the estimator by including only one observation for each textbook title. Using this treatment, the distribution of hazard function slightly shifts to the right, although the shape of the distribution changes little.

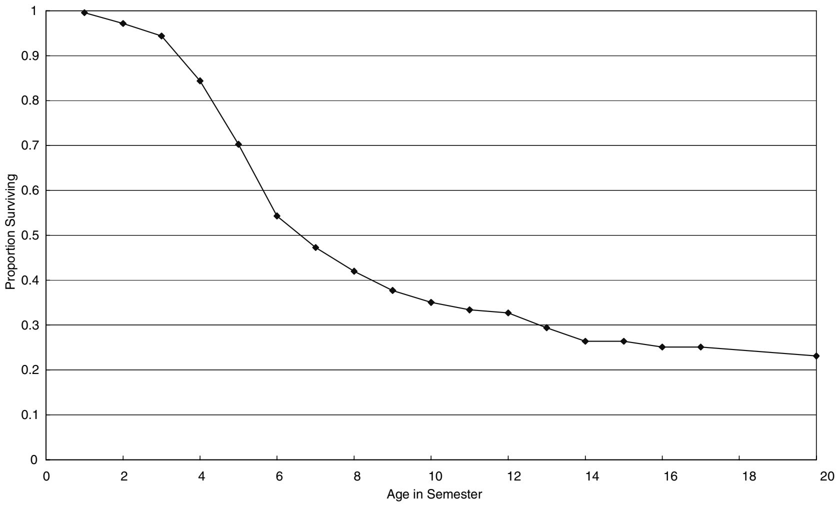

FIGURE 3. LIFE TABLE ESTIMATOR: SURVIVAL FUNCTION (TRUNCATED AT SEMESTER AGE = 20)

cycles after five, six, and seven semesters. It should be noted, however, in contrast to the popular notion that textbooks have a 3-year revision cycle, substantial variation occurs in the timing of textbook revisions. I note that there is an outlier that revised an edition after 60 semesters since publication (not shown in the figure). Estimation results are robust with or without this observation.

Figure 3 shows the survival function for the population using the life table analysis. Again, the x-axis is truncated at 20. The figure shows that median survival age is about seven semesters, indicating that half of the textbooks get revised within 4 years. The survival function becomes flat after around 20 semesters. This suggests the possibility that those textbooks that do not revise editions within 10 years or so may never revise editions at all. In fact, Figure 3 appears to indicate as much as 20% of the textbooks in the sample may never revise editions at all. Table I reports descriptive statistics.

4. The Model

4.1 Theoretical Considerations

In this section, I discuss the underlying economic factors that may affect the timing of new edition introduction. On the demand side, it is useful to recognize that two players are involved in buying a textbook, that is, teacher and student. In the first stage, the teacher of a course will decide

TABLE I.
DESCRIPTIVE STATISTICS

	Full Sample			Sub-Sample Exclude Titles That Follow the Three Year Cycle		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Revision	2,561	0.114	0.318	1976	0.096	0.294
Usedshare	2,561	0.419	0.262	1976	0.426	0.265
Usedshare (2nd semester)	1,694	0.286	0.160	1182	0.289	0.166
Age (in semester)	2,561	5.292	6.214	1976	5.849	6.910
Age squared	2,561	66.61	281.8	1976	81.92	319.1
Age cubic	2,561	1931	14885	1976	2480	16908
ln(age)	2,561	1.315	0.802	1976	1.389	0.836
Comp_rev	2,561	0.793	0.405	1976	0.788	0.409
# of competitors	2,561	18.23	12.46	1976	17.85	12.39
Market size (in 1000)	2,561	2.277	2.906	1976	1.754	2.295
Page number	2,491	595.1	213.1	1912	584.1	221.8
Height of textbook (in cm)	2,486	25.08	1.639	1907	25.02	1.708
Color	2,561	0.398	0.489	1976	0.171	0.377
Principles	2,561	0.418	0.493	1976	0.402	0.490
Intermediate	2,561	0.081	0.273	1976	0.059	0.236
Applied	2,561	0.501	0.500	1976	0.539	0.499
y97	2,561	0.211	0.408	1976	0.216	0.411
y98	2,561	0.203	0.403	1976	0.202	0.402
y99	2,561	0.191	0.393	1976	0.187	0.390
y00	2,561	0.200	0.400	1976	0.198	0.399
Fall	2,561	0.506	0.500	1976	0.508	0.500

which textbook should be adopted for her course. The teacher is likely to choose a textbook among alternatives by considering the quality of the textbook, cost to the students, and switching costs to herself. For example, if the textbook is out-of-date without being revised for a long time, the teacher may switch to a different textbook, and the demand for the textbook may decline. Thus, in the first stage, there will be substantial competition among publishers to be adopted for a course.

In the second stage, conditional on the teacher's adoption decision, the student will determine whether to buy a new textbook, used, or none at all. It is unlikely that other textbooks are included in the student's choice set, because textbooks not adopted for the course are likely to be poor substitutes. Thus, once a textbook is adopted for a course, the publisher has a monopoly, which is a unique feature of the textbook market.[18] The student will choose among new, used, or none at all by

18. However, due to the competition in the first stage, the monopoly power is likely to be limited. Waldman (2003, p. 144) has more discussion on this point.

maximizing the utility that she gains from each option. It is common that textbook publishers periodically introduce new editions of a textbook, which reduces the used market value of the current edition essentially to zero.[19] Thus, the student will form some degree of expectation about the timing of new textbook introduction and about the resale value of the textbook. The student may also place different valuation on used versus new textbooks depending on their intension to keep the textbook after the semester. For example, economics majors may place higher valuation on a new textbook than noneconomics majors because they are likely to continue using it after the semester. Thus, the student's problem is to choose among new, used, or none at all based on textbook prices, expected resale values, and their preferences on new versus used textbook.[20] Note that if the student foresees that a new edition will come out in the next semester, this may change her decision of buying between used, new, and none at all. This will create a potential endogeneity between textbook revision and the choice among used, new, and none at all.[21] I will address this issue in Section 6.4.

The publisher's problem is to decide when to introduce a new edition and how much to charge for the textbook over the life of each edition, given the consumer's preference on new versus used textbook and the cost of producing a textbook.[22] Introducing a new edition of a textbook will require the firm to incur a fixed cost of revising the current edition and has two effects: it improves the quality of the textbook by updating new information and it kills off the used market by reducing the used book value essentially to zero. Although frequent introductions of new editions may help eliminating the existing used texts, to the extent that consumers know that the effective life of a textbook is shortened, it will reduce the price that consumers are willing to pay

19. Once a new edition is released, college bookstores usually do not buy back an old edition.

20. Although writing down such a model is beyond the scope of this paper, we are currently developing such a model in a separate paper (please see Bond and Iizuka, 2005).

21. For example, suppose economics majors purchase a new book and keep it for future use, while noneconomics majors buy a used book and sell it after the semester. If students correctly anticipate that a new edition will come out in the next semester, used book purchases may decline because noneconomics majors cannot sell used books after the semester. New book purchases, however, may *not* decline because economics major's purchasing decisions are not affected by the existence of the used market. This will create an edogeneity between the used share and the timing of textbook revision. In fact, a careful observation of Figure 1 Panel A reveals that, in three textbooks out of four shown in the panel (i.e., textbooks B, C, and D), *UsedShare* drops immediately before the introduction of a new edition.

22. In this paper, I focus my analysis on the publisher's product introduction decision. Bond and Iizuka (2005) model the publisher's pricing problem over the life of an edition and test their predictions using data from the textbook market. They show that textbook prices can increase over the life of an edition and data support such a prediction.

for a new textbook. The publisher will determine the optimal "revision cycle" that maximizes profits by weighing these factors.

Ideally, one would like to estimate a structural model that explicitly considers the buyer and seller behavior discussed above. Moreover, given the oligopolistic nature of the publishing industry, it would be ideal to account for the oligopolistic interactions among the publishers. Although we begin to see such research in other markets (e.g., Esteban and Shum, 2005), these models are often restrictive. Instead, because this is the first attempt to empirically examine the new product introduction of durable goods producers facing used products, I approach this problem by estimating a reduced form regression. In particular, I focus my analysis on examining whether the following three factors affect the publisher's decision to introduce a new edition of the textbook.

The first factor is the extent of competition that new textbooks may face from the used units. As conventional wisdom suggests, the publisher may be inclined to introduce a new edition of the textbook to eliminate the stock of used textbooks. I compute the quantity share of used textbooks in each title-edition during each semester and examine whether the availability of used units affects the timing of new edition introduction. Second, I examine whether the time elapsed since the last revision affects the timing of new edition introduction. Textbook content may become obsolete over time, and this may reduce the willingness-to-pay of the student. It is also possible that professors may switch to a different textbook as the textbook becomes outdated. Because the speed at which textbook content becomes obsolete may differ across the categories, I allow this time effect to be different across textbook categories. The third factor that may affect the timing of new product introduction is the degree of competition among alternative new textbooks within each textbook category. Waldman (1996a) comments that durable goods producers are likely to exercise planned obsolescence when they have substantial market power. This is because when many alternative products exist in the market the competition between used versus new units becomes less important relative to the competition across different brands in the same market.

4.2 The Empirical Model

I use discrete-time survival models in order to examine the publisher's decision to introduce a new edition of a textbook. Corresponding to the nature of the data, I consider two mutually exclusive periods in each year, that is, fall and spring semesters. I count the duration until the transition of a state (or censoring) by the number of semesters using the positive integers, that is, 1, 2, 3, and so forth. The empirical model immediately follows the theoretical discussion in the previous section. In particular, I include three variables as the independent variables that correspond to the three main factors that may affect the publisher's new edition introduction. Specifically, I analyze the publisher's decision using the following variables:

$$Rev_{it+1} = f(UsedShare_{it}, \ln(Age_{it}), CompRev_{it+1}, MarketSize_i, Cost_{it}, \\ Category_k, Firm_j, Year_t, Spring),$$

where Rev_{it+1} is a revision indicator for the textbook title i during semester $t+1$, which equals 1 if the publisher introduces a new edition of the title in semester $t+1$, and 0 if otherwise.[23] $UsedShare_{it}$ is the quantity share of used textbooks for title-edition i in semester t. This captures the extent of competition a new textbook faces from used units, the variable of our main interest. Because it usually takes at least 1 year for the publisher to revise a textbook, I assume that the publisher correctly anticipates the market share of used units for the following semester. Based on this expectation, the publisher decides when to introduce a new edition of the textbook. I note, however, that if there is a difference between anticipated *UsedShare* and observed *UsedShare*, this will create a "errors in the variables" problem in the econometric sense. I discuss this issue in Section 6.4.

$\ln(Age_{it})$ is a natural logarithm of the number of semesters at semester t since the introduction of textbook title i (baseline hazard). This variable corresponds to the second theoretical factor discussed in the previous section. A positive coefficient for this variable implies that the probability of revision increases as the textbook gets older, conditional on the age of the textbook. We would expect a positive coefficient for this variable if the publisher finds it important to keep the content up-to-date.

In order to examine whether competitive forces drive revision decisions, I included a dummy variable, $CompRev_{it+1}$, which equals 1 when a competing textbook in the same textbook category revises the textbook in the next semester and 0 otherwise. I divide textbooks into 16 categories based on the grouping defined by MIR to construct this variable. As a similar measure, I also used the number of textbook titles in the textbook category i at semester t, measuring the extent of competition among the alternative textbooks within each category. We would observe a negative coefficient for this variable, if, as Waldman (1996a) argued, planned obsolescence is more likely when firms have

23. Although my data set ends in fall 2000, I searched Amazon.com and BN.com and checked if a new edition was introduced in spring 2001. Thus I have data for Rev_{it+1} up to spring 2001.

substantial market power. The results are robust regardless of the choice of a variable.

In addition to the above variables, additional factors may also affect the timing of textbook revision. These factors are primarily treated as controls in this paper, and I pay less attention to these variables. The first is the market size of textbook title *i*. If the market size of the textbook is large, the revision cycle is likely to be shorter, because the publisher can more quickly "finance" the fixed revision costs, holding all other factors constant. $MarketSize_i$ is the average number of textbooks sold per semester for textbook title *i* during the 10-semester period, including both new and used textbooks. Those semesters immediately before the introduction of a new edition are excluded from the calculation, because the student who anticipates a new edition in the next semester may not purchase the textbook in the current semester. The second is the amount of revision costs for title *i* during semester *t*, $Cost_{it}$. The publisher has to incur fixed costs to revise textbooks. If these fixed costs are large, the revision cycle is likely to be longer because the publisher needs a longer period to recoup fixed investments. I include three variables to capture these costs: number of pages, size of textbook, and whether color illustration is used in the textbook. These cost variables are also likely to capture the marginal cost of production. Unfortunately, I cannot distinguish the two explanations. $Category_k$ is a vector of 16 textbook category dummies such as "history," "international economics," and "microeconomics-principles." Again, I aggregate MIR's original textbook categories into 16 categories. Appendix shows all categories included in the estimation and how they correspond to MIR's original categories. $Firm_j$ includes seven major publishers as dummy variables to account for publisher fixed effects. Firms may employ different policies in terms of revision decisions of textbooks and may have different cost structures.[24] Finally, $Year_t$ and *Spring* are year and spring semester dummy variables.

5. Estimation

5.1 Discrete-Time Duration Model

In this section, I discuss the basic estimation approach. The following sections discuss three additional estimation issues relevant for the data and the questions I address in this paper.

24. The firms included as fixed effects are Worth Publishers, Houghton Mifflin, John Wiley & Sons, McGraw-Hill, Pearson Education, Thomson Learning, and W. W. Norton & Company.

Suppose T_i is a discrete-time random variable with probabilities

$$f_{ij} = \Pr(T_i = j),$$

where $j \in \{1, 2, 3, \ldots\}$ is the set of positive integers. I observe a textbook i's duration from semester $k = 1$ through to the end of semester T_i at which point the duration is either complete ($c_i = 1$), or right censored ($c_i = 0$). The discrete hazard is given by

$$h_{ij} = \Pr(T_i = j \mid T_i \geq j).$$

Ignoring delayed entry for the moment, the likelihood function is given by

$$L = \prod_{i=1}^{n} [\Pr(T_i = j)]^{c_i} [\Pr(T_i > j)]^{1-c_i},$$

where a completed duration contributes for the first part of the likelihood function, while a censored duration contributes for the second part. I can rewrite the likelihood function as

$$\begin{aligned} L &= \prod_{i=1}^{n} \left[h_{ij} \cdot \prod_{k=1}^{j-1} (1 - h_{ik}) \right]^{c_i} \left[\prod_{k=1}^{j} (1 - h_{ik}) \right]^{1-c_i} \\ &= \prod_{i=1}^{n} \left[\left(\frac{h_{ij}}{1 - h_{ij}} \right)^{c_i} \cdot \prod_{k=1}^{j} (1 - h_{ik}) \right]. \end{aligned}$$

The Log likelihood is

$$\log L = \sum_{i=1}^{n} c_i \log \left(\frac{h_{ij}}{1 - h_{ij}} \right) + \sum_{i=1}^{n} \sum_{k=1}^{j} \log(1 - h_{ik}).$$

Now, I can further rewrite this by defining a new binary variable y_{ik}, which equals 1 if the ith textbook has decided to revise an edition at $T_i = j$, and 0 if otherwise.

$$\log L = \sum_{i=1}^{n} \sum_{k=1}^{j} [y_{ik} \log(h_{ik}) + (1 - y_{ik}) \log(1 - h_{ik})].$$

Note that the likelihood L is the same form for the standard likelihood function for a binary regression model with event probabilities h_{ik}.

If I assume the hazard function follows the discrete proportional hazard model, the hazard ratio is given by[25]

$$h_{ik} = 1 - \exp[-\exp(\beta' X_{ik} + f(k))],$$

where X_{ik} is time-varying covariates, and $f(k)$ is baseline hazard during semester k.

For the basic specification, I specify the baseline hazard as a monotone increasing (or decreasing) function of time t, that is, $\ln(t)$, which is a discrete time analogue to a continuous-time Weibull model. I use this specification because I anticipate that the contents of textbooks become outdated over time, and thus the hazard rate increases as the book gets older.[26] Because the hazard rate may not change monotonically, I also estimate the model using the cubic polynomial specification for the time trend.

5.2 Multiple Editions Per Title

When examining the data, I often observe multiple editions of the same title. For example, I observe both the second and third editions of *Industrial Organization* by Carlton and Perloff in my data. Ideally, one would like to estimate a textbook fixed-effects model to control for unobserved product attributes that might be correlated with the variables of our interest. Unfortunately, the strategy does not work in this case because I still have many titles that do not revise editions during the 5 years I observe. If I estimate a fixed-effects model, then I have to drop these titles from the estimation because there is no change in the dependent variables (which equal zero) for these observations. This will reduce the number of observations by half. Moreover, analyzing this selected sample is problematic because it ignores a large number of textbooks that revise editions infrequently. As a result, estimated coefficients will be biased due to the sample selection problem. Because of this difficulty, I do not estimate a fixed-effects model. Instead, I include a number of variables, such as category dummies, in the estimation to control at least partially for the potential endogeneity.

Another challenge is that revision decisions of the same textbook-title are likely to be correlated across editions. I address this issue by computing robust standard errors that take into account the clustering at the title level. Note that this treatment assumes that, if there is more than one edition of the same title, the "failure" events (i.e., revision decisions) are of the same type and unordered within the different

25. An alternative to the proportional hazard model is the proportional odds model, that is, the logistic model. Estimation results change little when this model is used.

26. I also examine a "mover-stayer" model later in which I allow some proportion of textbooks to never be revised.

editions of the same title. Alternatively, one can consider a learning model in which publishers learn from the previous publishing cycle and update their beliefs over editions. This, in turn, requires one to treat the edition decisions as "ordered." This is certainly an interesting issue but one which requires more sophisticated modeling, and I will leave it for future study.

5.3 Delayed Entry or Left Truncation

The next issue is delayed entry or left truncation. For example, for all textbooks that were published before spring 1996, I cannot observe their history before fall 1995. Thus, these observations exhibit the delayed entry (or left truncation) problem. Fortunately, I am able to observe in the data when these textbooks were introduced before 1996, and thus can assign the semester age for the delayed entry observations. This age information allows us to include these observations in the estimation without much difficulty.[27]

5.4 Unobserved Heterogeneity

Standard survival models assume that all observations eventually "fail." In the current context, this implies that all textbook titles revise editions

27. To see this, recall that the likelihood function for observation i without delayed entry is given by:

$$L_i = \left(\frac{h_{ij}}{1-h_{ij}}\right)^{c_i} \cdot \prod_{k=1}^{j}(1-h_{ik}).$$

Suppose I do not observe i until time e_i in the data set, that is, delayed entry. In this case, since I observe these textbooks conditional on the survival up to e_i, I have to adjust their likelihood contributions by taking this into account. The likelihood contribution for i is given by:

$$L_i = \frac{\left(\frac{h_{ij}}{1-h_{ij}}\right)^{c_i} \prod_{k=1}^{j}(1-h_{ik})}{S(e_i)}.$$

Note, however, the survivor function for this observation up to e_i is given by:

$$S(e_i) = \prod_{k=1}^{e_i}(1-h_{ik})$$

and this leads to a "convenient canceling" result (Jenkins, 1995):

$$L_i = \left(\frac{h_{ij}}{1-h_{ij}}\right)^{c_i} \left[\frac{\prod_{k=1}^{j}(1-h_{ik})}{\prod_{k=1}^{u_i}(1-h_{ik})}\right] = \left(\frac{h_{ij}}{1-h_{ij}}\right) \prod_{k=e_i}^{j}(1-h_{ik}).$$

That is, I can correctly incorporate the delayed entry observations by including only the periods after they entered the data set.

with probability one. However, it is plausible that some textbooks covering "classic" contents, such as Adam Smith's *The Wealth of Nations* or basic mathematical techniques, may never revise editions perhaps because they may never become obsolete. If so, this implies that I have two types of textbooks in the population, that is, "mover" and "stayer." This is a relevant concern for my data because, as shown in Figure 3, many textbook titles did not revise editions during the period I observed. Lancaster (1979) showed that, if such unobserved heterogeneity exists, treating the population as a homogeneous one may lead to erroneous conclusions on duration dependence and bias coefficients.

Note that I have already addressed this issue at least partially by including category specific dummy variables. If the distinction between "movers" and "stayers" are determined primarily by textbook categories, the textbook category dummies should be able to account for the problem. If, however, "movers" and "stayers" exist in the population even after controlling for the textbook categories, then allowing unobserved heterogeneity would further improve the estimation results. In fact, the breakdown of Figure 3 indicates that such a treatment may be useful. For example, even after controlling for textbook categories, the life table estimators (not reported) show that 19.2%, 20.9%, and 18.7% of the "introductory," "history," and "international" textbooks do not revise editions, respectively.

I deal with this potential problem by estimating a simple model that assumes a fraction p of the population to be "stayers" who never introduce a new edition. Censored observations consist of two cases: (1) those who eventually revise editions, but have not yet done so, and (2) those who never revise editions. Thus the likelihood function can be written as:

$$L = \prod_{i=1}^{n} [(1-p)\cdot \Pr(T_i = j)]^{c_i}[p + (1-p)\cdot \Pr(T_i > j)]^{1-c_i}.$$

If we find $p = 0$, it implies that all textbooks eventually revise editions, and this reduces to the standard survival model without population heterogeneity. I test this hypothesis by using the likelihood ratio test.

6. Results

6.1 Base Results

Table II shows the results using all sample. The first column examines the average effect of *UsedShare* and ln(*Age*) on the probability of revising a textbook edition. All models include 16 textbook category dummies (the omitted category is "history"). I report hazard rates corresponding to

Table II.
Textbook Revision Hazard Estimates (1)

	(1) Full-Sample Average Effects	(2) Full-Sample Heterogenous Effects	(3) Excl. 3-Year Cycles Average Effects	(4) Excl. 3-Year Cycles Heterogenous Effects
Usedshare	4.2307***		3.0908***	
	(1.3723)		(1.2627)	
Usedshare ∗ principles		2.2004*		1.4986
		(0.9578)		(0.8173)
Usedshare*intermediate		3.5126		21.703*
		(4.0614)		(35.537)
Usedshare ∗ applied		4.9698***		3.3025**
		(2.2359)		(1.7917)
ln(age)	2.4946***		1.9751***	
	(0.5427)		(0.4888)	
ln(age) ∗ principles		5.3987***		4.1585***
		(1.2130)		(1.0597)
ln(age) ∗ intermediate		5.0581***		2.7064*
		(2.2866)		(1.4334)
ln(age) ∗ applied		1.6316**		1.4048
		(0.3953)		(0.3622)
Competitor revision	1.1251	1.1246	1.2956	1.3054
	(0.2081)	(0.2071)	(0.2942)	(0.2972)
Market size	1.0960***	1.1044***	1.1251***	1.1433***
	(0.0244)	(0.0260)	(0.0340)	(0.0367)
Spring	0.5595***	0.5523***	0.5759***	0.5637***
	(0.0791)	(0.0783)	(0.0933)	(0.0917)
Introductory	2.0671*	0.4251	1.6166	0.4182
	(0.7677)	(0.2899)	(0.6334)	(0.2842)
Macro-principles	1.8541	0.3876	1.2384	0.3194
	(0.7165)	(0.2748)	(0.5457)	(0.2352)
Macro-intermediate	2.7888**	0.4199	1.7424	0.1795
	(1.1410)	(0.3771)	(0.7207)	(0.1890)
Money and banking	1.6476	1.3974	1.4033	1.2801
	(0.8256)	(0.6363)	(0.9398)	(0.7957)
Labor	2.0798*	1.9241*	1.4980	1.4114
	(0.8855)	(0.7296)	(0.5633)	(0.4870)
International	2.5894**	2.0857**	1.5655	1.3288
	(0.9986)	(0.7387)	(0.7413)	(0.5803)
Micro-principles	1.9251*	0.4099	1.1637	0.3042
	(0.7539)	(0.2860)	(0.5215)	(0.2244)
Micro-intermediate	2.5583***	0.4146	1.9394	0.1919
	(0.9265)	(0.3585)	(0.8147)	(0.2161)
Managerial	2.3973**	1.9911*	1.3049	1.1202
	(0.9824)	(0.7414)	(0.5697)	(0.4512)
Public finance	1.8937	1.6477	1.2992	1.1858
	(0.8877)	(0.6912)	(0.6962)	(0.5826)

Continued

Table II.
Continued

	(1) Full-Sample Average Effects	(2) Full-Sample Heterogenous Effects	(3) Excl. 3-Year Cycles Average Effects	(4) Excl. 3-Year Cycles Heterogenous Effects
Environmental	1.3908	1.2353	0.7919	0.7377
	(0.7479)	(0.6011)	(0.5021)	(0.4366)
Econometrics	2.9672**	2.8668**	2.6399*	2.4676*
	(1.5395)	(1.3562)	(1.4444)	(1.2460)
Macro-other	4.2644***	3.6454***	3.3421***	2.9638**
	(1.7802)	(1.3617)	(1.5417)	(1.2542)
Micro-other	1.2022	1.4640	0.8327	0.9826
	(0.7017)	(0.7322)	(0.5464)	(0.5665)
All other	2.4551*	2.4108*	1.8006	1.8277
	(1.3101)	(1.1631)	(1.1079)	(1.0193)
Year dummies	Included	Included	Included	Included
Cost variables	Included	Included	Included	Included
Publisher dummies	Included	Included	Included	Included
Observations	2472	2472	1893	1893
Log likelihood	−768.469	−755.85	−535.58	−527.46

Standard errors (in parentheses) are adjusted for clustering on textbook title.
*significant at 10%; **significant at 5%; ***significant at 1%.
Reported hazard ratios are univariate transformation of the estimated betas for the original survival model, that is, hazard ratios, HRb = exp(b). Reported standard errors are also a transformation using the delta rule, that is, se(HRb) = exp(b) ∗ se(b). Reported significance level is obtained from the test statistics for the original duration model.

regression coefficients. Robust standard errors that take into account the clustering at the textbook title level are reported in the parenthesis. I find that the hazard rate for *UsedShare* is positive and statistically different from zero, suggesting that the publisher is more likely to revise editions as the market share of used textbooks increases, holding all other factors constant. This is consistent with the view that textbook publishers introduce new editions to kill off used textbooks. The hazard rate for ln(*Age*) is also positive and statistically significant, suggesting that hazard rate increases as the time because previous revision increases. The hazard rate for the rival's new edition introduction is positive but not statistically significant, suggesting that competitive forces may not be important in publisher's revision decisions. The result does not change even if I use instead the number of competitors in the same category (not reported).[28]

28. This may be an interesting finding in reference to Waldman's (1996b) argument that planned obsolescence is likely to be present in markets where firms have substantial market power. One explanation for this result is that the substitutability of textbooks is not very high even within the same category, possibly due to the high switching cost to the teacher.

Table III, column 2 reports the results when I allow heterogeneous responses to *UsedShare* and ln(*Age*). The impact of used market share on textbook revision may be different across textbook categories. Similarly, the advance of economics discipline may be different across categories,

Table III.
Textbook Revision Hazard Estimates (2)

	(1) Split Population Average Effects	(2) Split Population Heterogenous Effects	(3) 2nd Period Used Share Average Effects	(4) 2nd Period Used Share Heterogenous Effects
Usedshare	5.2912***			
	(1.9352)			
2nd period usedshare			2.0608	
			(1.2875)	
Usedshare ∗ principles		2.1027		
		(1.1091)		
Usedshare ∗ intermediate		2.9058		
		(3.7777)		
Usedshare ∗ applied		9.0190***		
		(5.9976)		
2nd period usedshare ∗ principles				1.4639
				(1.1152)
2nd period usedshare ∗ intermediate				2.4788
				(5.4800)
2nd period usedshare ∗ applied				9.3453**
				(10.184)
ln(age)	3.0406***		18.606***	
	(0.4457)		(5.6163)	
ln(age) ∗ principles		14.800***		14.814***
		(6.0494)		(5.1829)
ln(age) ∗ intermediate		7.5527***		144.43***
		(4.2461)		(180.51)
ln(age) ∗ applied		1.8690***		22.998***
		(0.3268)		(12.986)
Competitor revision	1.1908	1.1474	1.0831	1.0703
	(0.2334)	(0.2256)	(0.2772)	(0.2802)
Market size	1.0913***	1.0876***	1.0685***	1.0659***
	(0.0204)	(0.0235)	(0.0243)	(0.0237)
Spring	0.5526***	0.5283***	0.4333***	0.4268***
	(0.0701)	(0.0692)	(0.0796)	(0.0777)
Introductory	2.4704*	0.2049*		
	(1.2374)	(0.1785)		

Continued

Table III.
Continued

	(1) Split Population Average Effects	(2) Split Population Heterogenous Effects	(3) 2nd Period Used Share Average Effects	(4) 2nd Period Used Share Heterogenous Effects
Macro-principles	2.3261	0.2040*	0.7710	0.7448
	(1.2069)	(0.1790)	(0.2938)	(0.2723)
Macro-intermediate	3.1930**	0.5022	1.6158	0.0334
	(1.7947)	(0.6016)	(0.6895)	(0.0765)
Money and banking	2.0881	1.8079	0.8678	0.2040
	(1.4212)	(1.2747)	(0.6480)	(0.3134)
Labor	2.0957	1.9330	1.0887	0.2752
	(1.2271)	(1.1405)	(0.6485)	(0.3720)
International	2.9653**	2.3665	1.0835	0.2729
	(1.5864)	(1.3093)	(0.4488)	(0.3399)
Micro-principles	2.5922*	0.2345*	0.6992	0.7024
	(1.3526)	(0.2042)	(0.2688)	(0.2584)
Micro-intermediate	2.7849**	0.4032	0.8260	0.0158*
	(1.4581)	(0.4960)	(0.3251)	(0.0397)
Managerial	2.8280*	2.2048	1.3037	0.3900
	(1.5846)	(1.2749)	(0.4363)	(0.4592)
Public finance	2.4378	2.1822	1.4913	0.4143
	(1.4560)	(1.3353)	(0.5972)	(0.5026)
Environmental	2.5037	2.0213	0.6764	0.1488
	(1.7665)	(1.4567)	(0.3146)	(0.1972)
Econometrics	3.3220**	3.6403**	0.5829	0.1862
	(1.9645)	(2.2587)	(0.4481)	(0.2712)
Macro-other	5.1990***	4.4235***	1.3802	0.4504
	(2.6497)	(2.3552)	(0.7565)	(0.6212)
Micro-other	1.5205	1.9183	1.9806*	0.6520
	(0.7961)	(1.0543)	(0.7840)	(0.7563)
All other	3.6078**	3.6196*	2.8591*	0.8462
	(2.3314)	(2.6095)	(1.6791)	(1.1898)
Year dummies	Included	Included	Included	Included
Cost variables	Included	Included	Included	Included
Publisher dummies	Included	Included	Included	Included
Observations	2472	2472	1599	1599
Log likelihood	−766.67	−747.35	−415.07	−411.81
p = Pr(never revise)	0.0999**	0.1567***		
	(0.0541)	(0.0497)		
Likelihood ratio test of $p = 0$	Prob = 0.03	Prob = 0.00		

Standard errors (in parentheses) are adjusted for clustering on textbook title.
* significant at 10%; ** significant at 5%; *** significant at 1%.
Reported hazard ratios are univariate transformation of the estimated betas for the original survival model, that is, hazard ratios, HRb=exp(b). Reported standard errors are also a transformation using the delta rule, that is, se(HRb) = exp(b)∗se(b). Reported significance level is obtained from the test statistics for the original duration model–H0: b = 0. These procedures are common in standard statistical packages such as STATA.

and thus some textbook categories may become obsolete more quickly than others. Ideally, one would like to allow all textbook categories to respond differently to *UsedShare* and ln(*Age*), but the data limitation does not allow me to include exhaustive interaction terms with the 16 categories. As an alternative, I create three mutually exclusive "major" categories, "principles," "intermediate," and "applied economics," where the type of students taking these courses are likely to be different, and allow these major categories to respond differently to *UsedShare* and ln(*Age*). The "principles" category includes textbooks used in introductory classes, containing the subcategories "introductory," "principles," "micro principles," and "macro principles" as defined by MIR. Similarly, the "intermediate" category includes "micro intermediate" and "macro intermediate" subcategories. The remaining textbooks are categorized as "applied." These three categories consist of 42%, 8%, and 50% of the entire sample, respectively.

All of the coefficients for *UsedShare* interacted with the three major categories are positive, but it is statistically significant only for the "applied" category and weakly significant for the "principles" category. The point estimate is the largest for "applied," followed by "intermediate," and "principles," suggesting that "applied" textbooks respond most sensitively to the accumulation of used books and revise textbooks when used books increase. In contrast, the revision decision of "principles" textbooks is least affected by the increase in used texts. The coefficients for ln(*Age*) interacted with the three categories are also all positive and statistically significant, indicating that hazard rate increases for all three categories as the textbook becomes older. Moreover, the coefficient for ln(*Age*) interacted with "principles" and "intermediate" are statistically larger than that for the "applied" category at the 5% confidence level. This suggests that the time since introduction has a much larger impact on the decision of revising editions for the "principles" and "intermediate" category than the "applied" category. As in the previous model, the rival firm's revision decision does not have a significant impact on own revision decision.

Combined together, the above analysis suggests that the major determinants of textbook revision are different across textbook categories. For the "principles" and "intermediate" categories, revision decisions are mostly driven by the time since introduction, while the accumulation of used texts play a relatively minor role for these categories. In contrast, the used market share significantly affects the publisher's revision decision for the "applied" category and the time since introduction is less important relative to its importance to the "principles" and "intermediate" categories. There is a popular notion that textbooks follow a predetermined "3-year" revision cycle, which implies that the accumulation of used texts do not play a role in the introduction of a new edition. The above evidence suggests that there is some truth to this view in the "principles" and "intermediate," but in the "applied" category accumulation of used texts plays an important role in the publisher's revision decision.

I report hazard rates in Table II, so it is easy to interpret and compare the numbers. For example, the coefficient for *UsedShare* reported in the first column suggests that, in a typical textbook category, hazard rate increases more than three times (more precisely, 323%) as the used market share increases from zero to one. This suggests that the availability of secondhand textbooks substantially affects the publisher's decision to introduce a new edition of the textbook. Similarly, the hazard rate for ln(*Age*), 2.49, implies that hazard rate increases by 150% if ln(*Age*) increases by one. This means, for example, textbooks after six semesters are more than 1.5 times likely to revise edition than textbooks after two semesters.[29]

The other estimates in column 1 also provide additional insights into the publisher's new edition decision, although they are included primarily as controls. First, the hazard rate for average market size is positive and significant, suggesting that the publisher revises editions more frequently in larger markets. This is expected because a large market size allows the publisher to recover fixed investments more quickly, holding all other factors constant.[30] The spring dummy variable shows that textbooks are 44% less likely to revise editions in the spring semester. Hazard rates for all textbook categories are positive, suggesting that relative to the base category (i.e., "history"), other textbooks are more likely to revise editions. For example, hazard rates for "intermediate macro" and "international economics" textbooks are higher than that for "history" textbooks by 180% and 160%, respectively. These differences may indicate that textbook contents become outdated in different speeds across subject categories. Finally, cost variables included in the estimation have little explanatory power except for "size," which shows a positive impact on revision hazard (not reported individually).

6.2 Textbooks that Do Not Follow the "Three-Year Cycle"

In this section, I repeat the above analysis by excluding the textbook titles that have revised editions in 3 years (or six semesters). This exercise is

29. Ln(Age) corresponding to age = 6 and 2 are 1.79 and 0.69, respectively. Thus, ln(Age) increases approximately by one when a textbook's semester age increases from 2 to 6.

30. In addition to the level of sales, I have also estimated the model by including the change of new textbook sales. Qualitative results did not change due to this addition.

intended to address the concern that the publisher may simply follow the predetermined "3-year revision cycle" regardless of the market condition.[31] In Section 3.1, I have already shown a substantial variation in the timing of revision. This section further attempts to address this concern by examining the subsample that clearly does not follow the 3-year cycle.[32] After dropping the titles that have revised editions in 3 years, the sample size is reduced to 1,893. Now the "principles," "intermediate," and "applied" categories consist of 40%, 6%, and 54% of the sample, respectively. This suggests that the textbooks in the "principles" and "intermediate" categories are more likely to follow the 3-year cycle than the other textbooks. The descriptive statistics for the sub-sample are reported in Table I.

Table II, columns 3 and 4 report the results. As before, column 3 shows the average effect of *UsedShare* and ln(*Age*), and column 4 allows the heterogeneous responses to these variables. The results in column 3 show that the hazard rate for *UsedShare* is positive and significant, suggesting that, on average, the increase of used market share increases the probability of introducing a new edition. The coefficient for ln(*Age*) is also positive and statistically different from zero. The point estimates for the two variables are slightly smaller than in model 1 but comparable. The results for other coefficients are also similar to the results from the full-sample. In particular, rival firm's revision decision does not significantly affect the publisher's revision decision. As in the full-sample case, the larger the market size, the more frequently the publisher introduces a new edition. Overall, the results suggest that the full sample results are robust even when I exclude observations that potentially follow the "3-year revision cycle."

Column 4 reports the results when I allow *UsedShare* and ln(*Age*) to have different effects across the three "major" categories. The hazard rates for *UsedShare* interacted with the three categories are positive, and they are significant only for the "applied" category and weakly significant for the "intermediate" category. The hazard rates corresponding to the interaction terms between ln(*Age*) and the three categories are also all positive but significant only for the "principles" category and weakly

31. Obviously, however, one has to wonder why the publisher chooses the "3-year cycle," if at all. Some textbook authors mentioned to me that their textbooks adopt a 3-year cycle, because, after 3 years, almost no new textbooks will be sold due to the accumulation of used textbooks. In fact, the publisher now asks them to revise a textbook every 2 years, because used textbooks accumulate more quickly today due to more efficient distribution in the secondhand market. These anecdotes suggest that the competition from used units may also explain the "3-year cycle."

32. In the earlier version of the paper, I have also estimated the model by dropping textbook titles that have revised editions in *less than* seven semesters. The results are similar to the results shown above.

significant for the "intermediate" category. As before, the point estimate for ln(*Age*) is the largest for the "principles" category. Thus, we continue to observe that *UsedShare* and ln(*Age*) play somewhat different roles in the publisher's revision decision depending on the textbook categories. In particular, although the time since last revision plays an important role in the "principles" textbooks, used share is not very important in the publisher's revision decision. In contrast, competition from the used units substantially affects the timing of revision in the "applied" category, but the "aging" of the textbook is not very important. Overall, the results are similar to the ones from the base model, even when the textbooks that may follow the "3-year cycle" are excluded.

6.3 Split Population Model

The first two columns in Table III report the results from the split population model. I use full sample to estimate the model. Here, a fixed proportion of population p is assumed not to revise editions at all, and I estimate p empirically. The qualitative results found in this model are very similar to the results reported in Table II, columns 1 and 2. Most importantly, publishers revise editions more frequently as the share of used textbooks increases. This is most clearly observed in the "applied" category. The hazard rate also increases as the time since previous revision increases. This effect is particularly important in the "principles" and "intermediate" categories. As before, competitor's revision decision has little explanatory power, confirming the previous results in Table II. Note that most of the estimated hazard rates are larger in absolute terms compared to the results reported in Table II, columns 1 and 2. This is expected because the "stayers," which do not revise editions at all, are separated from the "movers" in this estimation, and thus do not draw the estimated coefficients down to zero. The proportion p corresponding to the "stayers" is estimated to be between 0.10 and 0.16, suggesting 10 to 16% of all textbooks used in economics courses never revise editions. The estimated proportion of nonrevising textbooks is in agreement with the prior observation obtained from the survival function shown in Figure 3. I can reject the null hypothesis that $p = 0$ at the 1% confidence level.

6.4 Endogeneity Issue

As noted previously, our main variable of interest, *UsedShare*, may be endogenous if the student anticipates the timing of the introduction of a new edition and this affects her choice of buying a new versus used textbook. In addition, as discussed in Section 4.2, if there is a difference between the publisher's anticipation of used book share and observed used book share, this will create a "errors in the variables" problem in the econometric sense.

One way to deal with these problems is to use instrumental variables that are correlated with *UsedShare* but not with the error term. However, many observations in the data set are either left truncated or right censored, and, to my understanding, no satisfactory approach has been proposed for the instrumental variable censored duration model. The log-linear duration model, or accelerated failure time (AFT) model, can incorporate instrumental variables but only for the uncensored cases. It is also a common practice to implement instrumental variables in two stage: first regress *UsedShare* on instruments and plug in the predicted used share in the duration model. In the preliminary analysis, I have implemented this approach and the results (not reported) show that the coefficient for *UsedShare* is still positive and significant after using instruments, and the point estimate is larger than the base model.[33] Unfortunately, however, there is no guarantee that the two-stage instrumental variable approach provides consistent estimates in the context of nonlinear models such as the duration model.

Due to this difficulty, to deal with the first endogeneity issue, I have included *UsedShare* of *second semester* in place for *UsedShare* and re-estimated the model. If a textbook is not worth keeping, students will immediately resell the textbook after the semester, and used share will go up quickly. Thus, the second semester used share will be a good indicator for the general abundance of used books for each textbook. Moreover, because very few textbooks revise editions after two semesters, this variable is less affected by the possible change in buying a new versus used textbook immediately before the introduction of a new edition. The limitation, however, is that this variable does not vary over time and thus cannot fully account for the timing of revision. Moreover, the observations that do not have the second semester data have to be thrown away. Typically, this will eliminate old textbooks that have entered the data after second semester (i.e., delayed entry observations.).

33. I used two instruments for *UsedShare*. One instrument exploits the difference in transaction costs of holding used texts depending on how frequently a textbook is used. If a textbook is used in the previous semester, this would reduce the cost of holding used textbooks by sellers and distributors and thus likely to increase used share. As the second instrument, I used the number of textbooks sold in each category that would capture the extent to which noneconomics majors dominate the subject area. If noneconomics majors dominate a course, this will increase the number of used textbooks because those students would not keep textbooks after a semester. In general, economics courses that attract a large number of students tend to have a higher share of noneconomics majors.

Bearing these limitations in mind, I report the results in Table III, columns 3 and 4.[34] As usual, column 3 reports average effects, while column 4 allows heterogeneity across the three major categories. In column 3, the hazard rate for used share is positive but insignificant, suggesting that used share does not have a strong impact on revision decision at the aggregate level. On the other hand, the hazard rate for ln(*Age*) is positive and significant, replicating the results we found in the previous models. Column 4 reports the results with the interaction terms. First, similar to the previous models, all of the categories interacted with the used share are positive but it is significant only for the "applied" category. This provides additional support for the positive effect of used share on textbook revision. In addition, the hazard rates for ln(*Age*) interactions are also positive and significant, suggesting that hazard rate increases as the textbook gets older. One difference here, however, is that the point estimates for ln(*Age*) interacted with the three categories are larger than that from the base model. This may be because textbooks that last longer are likely to be dropped in this subsample because of left truncation. Overall, although point estimates are not directly comparable, qualitative results support the previous results from the baseline model.

To deal with the second potential endogeneity problem, that is, the "errors in variables" problem, second semester *UsedShare* discussed above is also useful. If I use second semester *UsedShare* as an independent variable and the publisher observes this variable before it decides to revise editions, there will be no "errors in variables" problem. As noted before, it takes about 1 year to revise a textbook. Thus, as far as the textbooks that revise editions immediately after the second semester are excluded, the above endogeneity concern can be minimized. The estimation results using this procedure (not reported) are not qualitatively different from the results reported in Table III, columns 3 and 4. This further confirms the robustness of the results.

6.5 Additional Robustness Check

In Table IV, I further examine the robustness of the results by changing the specification of the baseline hazard. The first two columns report the results when I use *Age* instead of ln(*Age*) in the baseline hazard specification. As before, the first column shows the results for the average effect of *UsedShare* and *Age*. The second column reports the

34. In this subsample, no "history" textbooks revise editions during the period we observe. Thus, "history" textbooks (48 observations) are dropped from the estimation. Accordingly, I assign the "introductory" category as the base category, and thus it is not shown in Table III, columns 3 and 4.

Table IV.
Textbook Revision Hazard Estimates (3)

	(1) Linear Age Average Effects	(2) Linear Age Heterogenous Effects	(3) Cubic Polynomial Average Effects	(4) Cubic Polynomial Heterogenous Effects
Usedshare	12.0744***		2.4197***	
	(3.2747)		(0.7644)	
Usedshare ∗ principles		5.5855***		1.3528
		(2.3941)		(0.5456)
Usedshare ∗ intermediate		10.8928**		1.6323
		(11.0661)		(2.0640)
Usedshare ∗ applied		9.3613***		3.0958**
		(4.1890)		(1.4310)
Age	1.0316**		2.4865***	
	(0.0152)		(0.2865)	
Age ∗ principles		1.2337***		66.458***
		(0.0560)		(54.620)
Age ∗ intermediate		1.2208***		87.161*
		(0.0878)		(204.01)
Age ∗ applied		1.0128		1.5878***
		(0.0168)		(0.2577)
Age sq.			0.9397***	
			(0.0091)	
Age sq. ∗ principles				0.6004***
				(0.0752)
Age sq. ∗ intermediate				0.5811**
				(0.1899)
Age sq. ∗ applied				0.9732**
				(0.0109)
Age cubic			1.0008***	
			(0.0001)	
Age cubic ∗ principles				1.0182***
				(0.0060)
Age cubic ∗ intermediate				1.0211
				(0.0144)
Age cubic ∗ applied				1.0003**
				(0.0001)
Competitor revision	1.1236	1.1281	1.0834	1.1145
	(0.2086)	(0.2087)	(0.2085)	(0.2080)
Market size	1.0909***	1.1012***	1.0978***	1.0852***
	(0.0223)	(0.0246)	(0.0179)	(0.0254)
Spring	0.5401***	0.5377***	0.5650***	0.5679***
	(0.0764)	(0.0760)	(0.0709)	(0.0814)

Continued

TABLE IV.
CONTINUED

	(1) Linear Age Average Effects	(2) Linear Age Heterogenous Effects	(3) Cubic Polynomial Average Effects	(4) Cubic Polynomial Heterogenous Effects
Introductory	1.5969	0.7439	2.0485	0.0009***
	(0.5412)	(0.3881)	(0.9244)	(0.0016)
Macro-principles	1.4886	0.6695	1.9160	0.0008***
	(0.5329)	(0.3678)	(0.8773)	(0.0015)
Macro-intermediate	2.8414***	0.7717	2.4000*	0.0003
	(1.0280)	(0.5401)	(1.2142)	(0.0014)
Money and banking	1.4515	1.3008	1.5262	1.4902
	(0.6608)	(0.5650)	(0.8517)	(0.7151)
Labor	1.9653*	1.8387*	1.9727	1.9131
	(0.7380)	(0.6517)	(1.1181)	(0.7980)
International	2.1693**	1.8803*	2.4569*	2.2666**
	(0.7776)	(0.6293)	(1.1962)	(0.8340)
Micro-principles	1.5280	0.7045	1.9919	0.0008***
	(0.5548)	(0.3794)	(0.9083)	(0.0016)
Micro-intermediate	2.2623**	0.6781	2.4277*	0.0003
	(0.7637)	(0.4377)	(1.1707)	(0.0014)
Managerial	2.2343**	1.8976*	2.2517	2.1132*
	(0.8287)	(0.6728)	(1.1201)	(0.8201)
Public finance	1.7615	1.5727	1.6431	1.6229
	(0.7520)	(0.6246)	(0.8432)	(0.7023)
Environmental	1.1830	1.1217	1.3919	1.2736
	(0.6220)	(0.5422)	(0.7935)	(0.6230)
Econometrics	3.7275***	3.2163***	2.4514	2.4451*
	(1.7049)	(1.4357)	(1.3444)	(1.1879)
Macro-other	3.7350***	3.3350***	3.5295***	3.4466***
	(1.4496)	(1.2127)	(1.6276)	(1.3330)
Micro-other	1.7075	1.7306	1.6992	1.6572
	(0.8419)	(0.7757)	(0.8060)	(0.7848)
All other	2.4264*	2.3354*	2.8088**	2.4764*
	(1.1952)	(1.0794)	(1.3158)	(1.3272)
Year dummies	Included	Included	Included	Included
Cost variables	Included	Included	Included	Included
Publisher dummies	Included	Included	Included	Included
Observations	2472	2472	2472	2472
Log likelihood	−794.17	−780.92	−744.78	−712.91

Standard errors (in parentheses) are adjusted for clustering on textbook title.
*significant at 10%; **significant at 5%; ***significant at 1%.
Reported hazard ratios are univariate transformation of the estimated betas for the original survival model, that is, hazard ratios, HRb=exp(b). Reported standard errors are also a transformation using the delta rule, that is, se(HRb) = exp(b)∗se(b). Reported significance level is obtained from the test statistics for the original duration model–H0: b = 0.

results when heterogneity across the "major" categories are allowed. Qualitative results are similar to the previous results. As shown in the first column, at the aggregate level, hazard rates for *UsedShare* and *Age* are positive and significant as in the base model. Column 2 also confirms that the effect of *UsedShare* and *Age* vary across textbook categories. However, log likelihood reported at the bottom of the table indicates that the log of age specification used in the base model fits the data substantially better.

Columns 3 and 4 repeat the above analysis by using a flexible baseline hazard function, that is, the cubic polynomial specification. This specification allows the hazard rate for revision to vary nonmonotonically with the time since the previous revision. The basic results are robust to this change. Hazard rates for used share shown in column 3 and 4 continue to be positive and significant with comparable point estimates. The baseline time trend variables also indicate that the time since the previous revision plays an important role in textbook revision. Particularly, there is a steep increase in the hazard rate immediately after the introduction of a new edition in the "principles" and "intermediate" categories, while the same effect is much weaker in the "applied" category.

In Table V, I re-estimate the base model by dropping the observations of one and two semesters after the release of a new edition.

Table V.
Textbook Revision Hazard Estimates (4)

	(1) Sem 1&2 Dropped Average Effects	(2) Sem 1&2 Dropped Heterogenous Effects
Usedshare	2.7783***	
	(0.8763)	
Usedshare ∗ principles		1.6970
		(0.6980)
Usedshare ∗ intermediate		2.5693
		(2.9949)
Usedshare ∗ applied		4.3090***
		(2.0588)
ln(age)	2.1132***	
	(0.4830)	
ln(age) ∗ principles		3.2371***
		(0.8897)
ln(age) ∗ intermediate		3.9710***
		(2.0515)
ln(age) ∗ applied		1.6300
		(0.4842)

Continued

Table V.
Continued

	(1) Sem 1&2 Dropped Average Effects	(2) Sem 1&2 Dropped Heterogenous Effects
Competitor revision	1.0804	1.0706
	(0.2044)	(0.2031)
Market size	1.0985***	1.1009***
	(0.0240)	(0.0250)
Spring	0.5494***	0.5410***
	(0.0821)	(0.0811)
Introductory	2.3550***	1.2216
	(0.7696)	(0.9404)
Macro-principles	2.3126**	1.2128
	(0.8010)	(0.9794)
Macro-intermediate	2.9065***	0.7501
	(1.1309)	(0.8369)
Money and banking	1.6717	1.5170
	(0.7931)	(0.6928)
Labor	2.1191*	2.0320*
	(0.8805)	(0.7946)
International	2.7645***	2.5289***
	(0.9344)	(0.8252)
Micro-principles	2.3182**	1.2263
	(0.8119)	(0.9659)
Micro-intermediate	2.6393***	0.7341
	(0.8600)	(0.8051)
Managerial	2.4893**	2.3799**
	(0.9602)	(0.8739)
Public finance	1.9001	1.7807
	(0.8262)	(0.7406)
Environmental	1.6139	1.4740
	(0.7650)	(0.6988)
Econometrics	2.8174**	3.0277**
	(1.3840)	(1.4207)
Macro-other	3.1481***	3.0141***
	(1.0960)	(1.0294)
Micro-other	1.3364	1.5555
	(0.7460)	(0.8230)
All other	1.6676	1.7124
	(0.8289)	(0.8302)
Year dummies	Included	Included
Cost variables	Included	Included
Publisher dummies	Included	Included
Observations	1753	1753
Log likelihood	−688.16	−684.67

Standard errors (in parentheses) are adjusted for clustering on textbook title.
*significant at 10%; **significant at 5%; ***significant at 1%
Reported hazard ratios are univariate transformation of the estimated betas for the original survival model, that is, hazard ratios, HRb=exp(b). Reported standard errors are also a transformation using the delta rule, that is, se(HRb) = exp(b)∗se(b). Reported significance level is obtained from the test statistics for the original duration model–H0: b=0.

This is intended to address the concern that the significant relationship between *UsedShare* and textbook revision may be driven by the "post new release" dip in the used share, because the used book share is the lowest immediately after the release of a new edition. As shown in columns 1 and 2, qualitative results are very similar to the previous results reported in Table II, columns 1 and 2, although the point estimates changed slightly due perhaps to the change in the sample. Thus, the results are not driven by the "post new release" dip alone.

7. Conclusions

Two vastly different views exist on why durable goods producers periodically introduce new products. Although a popular argument is that producers introduce new models to kill off used units, others have argued that used units do not compete against new units because initial price alone can capture the net present value of all future transactions. In this paper, I attempted to sort out the alternative views empirically, using data from the textbook market. I found that textbook publishers revise editions more frequently as the market share of used textbooks increases, holding all other factors constant. This supports the view that the publisher introduces new editions to kill off used units. At the same time, however, the data also indicates that the time since previous revision plays an important role in determining the timing of revision. Thus, in contrast to the popular notion, publishers' frequent revisions cannot be attributed to planned obsolescence alone. Regarding the effect of competitive forces, I did not find the evidence that within category competition among textbook publishers affect the timing of revision.

In the textbook market, some model assumptions underlying Swan's classic results are likely to be violated. For example, new and used textbooks are clearly not perfect substitutes. Moreover, contrary to Swan's assumption, it is likely that consumers have heterogeneous preferences in holding durables, for example, depending on their majors. These characteristics of the market may explain why the publisher's revision decision appears to be affected by the presence of used products in the textbook market.

Appendix: Textbook Categories Included in the Estimation

Category Number	Category Name	Original MIR Category Names
1	Introductory	Introductory, Principles
2	History	History
3	Macro-principles	Macro-Principles
4	Macro-intermediate	Macro-International
5	Money and Banking	Money and Banking
6	Labor	Labor
7	International	International
8	Micro-principles	Micro-Principles
9	Micro-intermediate	Micro-Intermediate
10	Managerial Economics	Managerial Economics
11	Public Finance	Public Finance, Government and Business
12	Environmental	Environmental
13	Econometrics	Introductory Econometrics
14	Macro-other	Macro All Other, Macro-Advanced, Econ. Development and Planning, Forecasting, Econ. Of Developing Nations, Comparative Economic Systems
15	Micro-other	Micro All Other, Micro-Advanced, Industrial, Health, Urban Economics, Game Theory, Statistical Methods, Mathematical Economics, Theory
16	All-Other	All Other

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