Commitment, Vertical Restraints, and Dynamic Pricing of Durable Goods

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Abstract

A fixed price agreement regulated the retail pricing in the Norwegian book market when a legislation change led to a weakening of the price restraints. Two changes in the lifecycle sales followed: the industry shifted to a price skimming model and demand shifted from high prices in the introductory period to lower prices later in the lifecycle. While vertical price restraints are commonly thought of as restricting retail price levels, the evidence shows that the fixed price agreement restricted the price paths. I ask if a shift to a price skimming price model is profitable to the industry. The question turns on consumers’ time preferences. If consumers are myopic, then the fixed price agreement precludes profitable price skimming. If consumers are forward looking, then by committing the industry to a fixed price, then the agreement can be profitable by discouraging consumers from strategically delaying their purchases in anticipation of future discounts. The profitability of the fixed price agreement is compared to standard vertical restraints without commitment using a dynamic market equilibrium model with forward-looking demand side and a forward-looking supply side at parameters estimated from the data. I find that though the fixed price agreement increases industry profits above no price coordination, a dynamic two-part tariff without commitment is more profitable.

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1 Introduction

Fixed price agreements regulate pricing of books in many countries.\footnote{Fixed price agreements are regulate book markets in France, Germany, Austria, Netherlands, Lebanon, Italy, Spain, Portugal, Greece, Hungary, Israel, Slovenia, Argentina, South Korea, Japan and Mexico \cite{InternationalPublishersAssociation2014}.} The agreements hold that each publisher decides the retail prices of its titles for a limited time period, e.g. one year. The agreements are either codified as a voluntary and enforceable trade agreement between associations of booksellers and publishers or by government law.

A fixed price agreement imposes a vertical restraint known as Resale Price Maintenance (RPM) industry wide. Under RPM, the manufacturer decides the retail price. RPM is traditionally thought of as a channel strategy that coordinates the retail price level. RPM can effectively set a price ceiling \cite{Spengler1950}, which prevents double marginalization, or RPM can effectively set a price floor. A price floor can dampen price competition between retailers, which gives the retailers incentives to provide complementary services \cite{Telser1960}.

While RPM is a bilateral contract between a manufacturer and a retailer, a fixed price agreement is an enforceable multilateral agreement. Since the agreements are either voluntary, or typically endorsed by the industry when governed by law, it seems the agreements solve a price coordination problem that standard, bilateral vertical contracts can not solve.

As the publishers can not revise the fixed price in the restraint period, a fixed price agreement commits the industry to not only a price level in the restraint period, but also to particular price path. In this paper, I ask if fixed price agreements can coordinate lifecycle pricing by committing the industry to a price path that publishers and their retailers members may find hard to credibly commit to on their own. In a market for durable goods and forward-looking consumers, commitment to a price path can be a profitable strategy.

In this paper, I ask what the value the commitment to a fixed price has to the industry. The question is motivated by a change in the Norwegian Competition Act in 2005 which forced a revision of the fixed price agreement \("Agreement\). Following a political process, described in Section \ref{sec:Agreement}, the price restraint period in the new Agreement was shortened by about eight months and softened from a retail price point to a retail price interval. While standard theories of RPM predict a shift in price levels, the evidence in Section \ref{sec:Phasing} shows that the weakening of the price restraints instead shifted the industry towards a price skimming model.

Price skimming is a strategy that price discriminates consumers by lowering the price over time. In a market with myopic consumers, price skimming can be a profitable price discrimination strategy that lets high willingness-to-pay purchase early in the lifecycle at a high price, while consumers with lower valuations purchase later at lower prices. Forward-looking consumers may however strategically postpone their pur-
chases in anticipation of future discounts and the seller finds itself competing against its own future prices. Expectations of future discounts can even become self-fulfilling as shrinking current demand forces the seller to further discount to retain profits. Coase (1972) pointed out that in the limit, prices will immediately unravel to costs, and even a monopolist may fail to turn a profit. The impact of intertemporal substitution by forward-looking consumers on the profitability of price skimming has received broad attention in the theory literature since Coase, see Waldman (2003) for a survey.

Stokey (1979) shows that faced with consumers as forward looking as itself, a monopolist seller of a durable good would in fact prefer to not price skim at all, but rather commit to charge a constant price. The Agreement can credibly convince consumers to purchase early as the retailers can not discount the titles within the restraint period. By giving up control over its own future prices, the seller can therefore curb the competition from its own future prices. In this paper, I use the change in the Agreement as a natural experiment in vertical restraints that allows a comparison of the profitability of a vertical restraint with commitment to a set of pricing strategies without commitment.

The profitability of the shift to a price skimming strategy depends on the consumers price expectations and their willingness to substitute over time. Whereas the shift in pricing strategies are directly observable, consumers price expectations and time preferences must be inferred from the sales data. I estimate a dynamic discrete choice model of demand (Rust (1994)) on market level data that allows for substitution between retailers and over time. Using the identification strategy in Abbring and Daljord (2017), the shift in lifecycle sales following the new Agreement is taken as informative of consumers time preferences. The strategy exploits that at virtually the same introductory prices, consumers purchased a smaller share of lifecycle demand in the introductory period under the new Agreement. The shift in lifecycle pricing and demand is consistent with forward-looking consumers substituting towards future expected discounts as the industry shifted to a price skimming model.

Since the Agreement also regulates price competition between retailers for the same titles, i.e. intrabrand competition, a simple comparison of the industry profitability under the old and new Agreement conflates the value of commitment with coordination of price competition between retailers. Moreover, since it is not publicly known which vertical contracts the industry switched to under the new Agreement, it is unclear which benchmark contract a before-and-after to compare against. I therefore turn to an analysis of counterfactual vertical contracts in Section 9.

The counterfactual analysis compares the profitability of vertical restraints with commitment, such as under the old Agreement, to standard alternative, bilateral vertical contracts, such as dynamic two-part tariffs and linear contracts which do not offer commitment. The estimated demand model enters a market equilibrium model where a monopolist publisher supplies an oligopoly of retailers using vertical contracts. The vertical contracts considered vary with the level commitment and retail price coordination they provide. The vertical restraints, or lack thereof, affect both the consumers
price expectations and the retailers price incentives. The value of commitment to a particular price path depends on the consumers’ time preferences.

While the observed changes in the prices and sales following the new Agreement are consistent with an industry that lost commitment power, the counterfactual analysis in Section 10 shows that value of commitment to a fixed price is modest. For instance, at an estimated discount factor of 0.780, the profitability of the Agreement relative to a dynamic two-part tariff, which coordinates intrabrand pricing without commitment, is −2.49% for a typical title and −9.79% for a bestseller. In comparison, no intrabrand price coordination reduces the industry profits by an estimated −3.79% for a typical title and −22.50% for a bestseller. The evidence therefore shows that though the Agreement offers commitment, the industry can achieve higher profits by using vertical restraints to implement coordinated price skimming without commitment.

The analysis uses concepts and frameworks from the mostly distinct literatures on vertical contracts and dynamic pricing. Coasian dynamics have recently been studied empirically in a variety of markets, such as college textbooks (Chevalier and Goolsbee (2009)), consumer electronics (Conlon (2012)), video games (Nair (2007)), fashion goods (Krishnamurthi and Soysal (2016)), and sports event tickets (Sweeting (2012)). There is a rich theory literature on the effects of vertical contracts and channel coordination across the fields of operations research, economics, and marketing, see Cachon (2003) for a survey, but there are few studies of channel coordination in markets for durable goods. One exception is Desai et al. (2004), which develops a theory for a dynamic, channel-coordinating two-part tariff in a two-period durable goods market with forward-looking consumers. I use a similar concept as the basis of one of the counterfactual vertical contracts in the analysis.

This paper relates to a literature of empirical evidence on vertical contracts and channel coordination, e.g. Besanko et al. (2005) on retail pass-through, Villas-Boas (2007) on identification of unobserved vertical contracts, Ho et al. (2012) on full line forcing in the video rental industry, Mortimer (2008) studies revenue sharing in the same industry, Hristakeva (2017) on vendor contracts, and Asker and Ljungquist (2010) on the impact of vertical integration in investment banking. None of these studies however explicitly considers dynamic effects of vertical restraints.

2 Natural experiment

The old Agreement dated back to the 1960s. The Agreement was a voluntary and legally binding contract between the Association of Booksellers and the Association of Book Retailers that specified the terms of sales in the industry, including the price restraints.

The price restraints had two key components. The publisher specified a time-limited fixed price restraint for a title, and there was an industry coordinated clearance sale

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2See “Bokavtalen” in Store Norske Leksikon (Norwegian Encyclopedia) at www.snl.no.
following the expiration of the price restraint period. In combination, these com-
ponents imply a price path. The fixed price was often hard printed onto the cover of
the book, which served as an announcement of the retail prices to consumers. There
was little price promotion in the industry, except for the yearly, industry coordinated
clearance sale, which was trade marked (‘Mammut’) and heavily advertised.

Two features of the Agreement stand out. Firstly, the Agreement did not specify
the price level, but implicitly specified a price path. Each publisher could fix the retail
price at any level, but once set, the retailers had to respect the fixed price over the
restraint period. At the expiration of the restraint period, prices dropped by about
40% at the clearance sale, see Section 4.

Secondly, the Agreement’s clause 5 specified arbitration clauses in case of non-compliance.

Violation of the provisions of this Agreement may be prosecuted and, if necessary,
by any of the two associations, any publisher and any bookstore or combinations
of these who through their union are affiliated by the Trade Agreement. Each
association further commits to, within the framework of the individual association
bylaws, to take appropriate measures against its own members who may be guilty
of violations of this Trade Agreement.

Though the price restraint was a bilateral agreement between a publisher and a price
restraint, the arbitration clause exposes the vertical unit, i.e. a publisher and a re-
tailer, to potential legal action by rival firms if the vertical unit was to deviate from
the chosen price level in the restraint period. Beyond allowing for legal actions of rival
firms, the Agreement also allowed the Associations to enforce further sanctions within
the confines of each associations bylaws.

The arbitration clauses hence open for external enforcement of a bilateral agreement
that commits both the publisher and the retailer to a price path. The threat of be-
ing taken to court, or made subject to other punishments, counteracts incentives to
deviate from the announced price path. The data in Figure 3 in Section 4 shows that
retailers for the most part complied with the restraints in the old Agreement.

As part of European legislative integration, the Norwegian competition act was aligned
with its European Union counterpart in 2004. Following the legislation change, the
Norwegian Competition Authority deemed the Agreement unlawful and called for abol-
ishment of a fixed price agreement in any form. As European integration is a political
process that evolves independently of developments in the Norwegian book industry,
the legislation change can be considered an exogenous change to the vertical restraints.

The industry voiced strong and united opposition against the new legislation. The

3The Trade Agreement has been suspected of facilitating horizontal collusion among publishers. The
idea is that with RPM, it is easier for publishers to detect deviations on observable retail prices than say
on unobservable and more flexible wholesale prices, see Jullien and Rey (2007) for one treatment of the
argument.
Association of Booksellers, the Association of Publishers and the Association of Authors rallied together against the new legislation and called for exemption from the competition law. The industry support of the Agreement suggests that it solves a coordination problem that standard bilateral vertical contracts cannot. Following a public debate, a political compromise was reached.

The new Agreement was effective from May 1st 2005. The main changes under the new Agreement were twofold:

- A *shortening* of the price restraint period by eight months, from the year of publication plus one year to the year of publication plus four months.
- A *softening* of the fixed price to a price band. Whereas the price restraint under the old Agreement was both a floor and a ceiling, the new Agreement gave retailers discretion to discount the fixed price by up to 12.5%.

The changes are illustrated in Figure 1.

![Figure 1: The price restraints followed calendar time. Some title a released early in the year and some other title b released later in the year would both have their price restraints lifted at the end of the following year under the old Agreement. Following the expiration of the price restraint period, the titles went to the clearance sale with discounts on average in the range of 40% to 50%. The end of the clearance sale marks the end of the lifecycle for the typical title. Under the new Agreement, the same titles a and b would again have their restraints lifted at the same calendar time, but now May 1st the year after publication rather than December 31st. The clearance sale continued to be held in spring, but was no longer part of the Agreement itself.](image)

The natural experiment is of the before-and-after kind. Ideally, we would have a control group for a diff-in-diff design, but valid control groups are hard to find. For instance, text books were exempt from the new Agreement, but the demand for text books is substantively different from the demand for fiction and non-fiction. To interpret the changes in the pricing strategies as caused by the change in the Agreements, we will have to assume that the market is otherwise in a steady state where the titles each year are distinct, but drawn from a stationary distribution which itself was not

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4Exemptions from the European competition law can be given for industries that make goods considered to be of particular importance to national identity and is widely allowed for cultural goods, see Canoy et al. (2005).

5To give some context of the media attention devoted to the new Agreement, a search on the keywords 'Book Trade Agreement' in Retriever, a comprehensive Scandinavian media archive, over the period of public debate gives about half the search hits that 'Salt Lake City Olympics' gives in a comparable period. The numbers offer some perspective of the media interest the new Agreement attracted in a nation where winter sports is popular.

6The new Agreement also implied changes for Bokklubben, a mail-order retailer which was allowed to discount a limited set of titles by up to 25% under the old Agreement, but which were subject to the same terms as all other retailers under the new Agreement. As Bokklubben had a negligible share of the book market, I abstract away from Bokklubbens role in the industry.
affected by the Agreement.

The Norwegian book market had a stable market structure. There were main five publishers and four main book retail chains. The following analysis assumes that the market under the old Agreement is a valid control group for what the market under the new Agreement would have been, but for the change in the vertical restraints.

3 Data

Scanner data on sales were collected from the four largest book retail chains. The data covers the legislation change effective in May 2005. The data make up about 50% of total national sales over the period. The data are aggregated over four months (tertiles), and across stores within each chain. Observations are on title level identified by an Electronic Article Number (EAN). The data contains observations about 27000 titles. The sales are long tailed, with about 2% of titles making up about half of the total sales.

The data are merged on the EAN identifier with a comprehensive catalogue of title characteristics provided by Bokdatabasen, an industry logistics company. The catalogue contains data on the fixed price, genres, and various other characteristics such as page counts, edition etc and is used by retailers for logistical purposes and ordering. Prices are calculated as revenue divided by quantity sold in each period for each chain. Interviews with industry representative indicate that pricing policies were mostly uniform within the chains. The summary statistics of the scanner data are given in Table 1.

Table 1: Summary statistics matched scanner data

<table>
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<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<tr>
<td>quantity</td>
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</tr>
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<tr>
<td>fixed price</td>
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<td>129.47</td>
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</tr>
</tbody>
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4 Impact of the legislation change

Figure 2 illustrates the legislation change within the window of the data. The lifecycle of a title is taken to be about three years. After three years in the market, the sales of most titles are exhausted. By then, all price restraints were lifted, both before and after the legislation change. There are two full life cycles in the data. These are the titles published in 2004, and the titles published in 2005. Ideally, we would compare the price and demand paths for a typical title over the lifecycle before and after the legislation change. The data however cover only one year of sales prior to the legislation change.

7There was one merger in the last tertile of 2007 between two of the main publishers.
To establish the lifecycle sales patterns before the changes, the prices and sales patterns are assumed to be comparable across cohorts within a given year, where a cohort is taken to all titles released in a given year. To compare sales across years, the titles each year is thought of as drawn from a stable distribution. Though the sales of individual titles cannot be directly compared, for instance each year has its own bestsellers, the assumption allows for comparisons of moments of the sales distribution across years.

A lifecycle price path is constructed before the legislation change by calculating the mean price path of new titles in 2004, splice it with the mean price path of one year old titles in 2004 and lastly, with the two year old titles in 2004. The resulting price path serves as a representative price path before the legislation change. Holding the release schedule fixed, which has support in the data, we can then make meaningful comparisons of the differences in sales before and after the legislation change.

The tertiles are labelled spring, summer and fall. The mean representative prices before and after the legislation change are graphed in Figure 3. The prices are normalized to the fixed price. The publishers set the fixed price at the introduction of a title in the market. A price of 1 implies that a title in that tertile on average retailed at the fixed price while a price of say 0.5 means a title retailed at 50% discount. The normalization allows comparison of price paths across different price points. The prices are plotted against time and contain a total of nine periods. Confidence intervals of the means are interpolated between the data points to display the variance. Standard errors are reported at non-standard levels to display visible patterns.

The retailers are seen to have largely respected the fixed price policy under the old Agreement. Titles were retailing close to the fixed price in the price restraint period. Towards the end of the restraint period, there are some signs of retailers allowing discounts on the fixed price, on average about 5%. The deviations show that the price restraints were effectively a price floor and not a price ceiling.

Note that as titles are released over the year of publication, the set of titles in the sample is growing.

It seems plausible that with a substantial shortening of the restraint period, the publishers could respond by changing their release data strategies. For instance, publishers might prefer to release titles earlier in the year be protected by the restraints for a longer period of time. Einav (2007) finds evidence of strategic timing of releases in the U.S. motion picture industry. There is however no clear evidence of changes in the release dates of titles after the new legislation. The muted response may be related to the seasonality of demand. For instance, fall is the season for premium fiction. It could be that it is more important to release a title in the market at peak demand than it is to lengthen the price restraint period.
The restraint period was followed by the industry coordinated clearance sale which saw average discounts on the order of 45%. The clearance sale marks the end of the lifecycle for most titles. The average prices are seen to increase some after the clearance sale. The bounce back may have a variety of causes. Firstly, there is a selection of particularly popular titles that still sell after the sale, and these titles may command higher prices. There are also seasonal patterns may also explain some of the price changes, with fall being the high season.

![Figure 3: Mean of retail prices normalized to the fixed price.](image)

![Figure 4: Lifecycle demand shares.](image)

With the new agreement, the retailers were allowed to discount the fixed price by up to 12.5% at discretion and the restraint period was shortened by eight months. The resulting price band is illustrated by the shaded area in Figure 3. Three changes stand out.

Firstly, the retailers’ discretion to discount the fixed price by up to 12.5% under the new Agreement went largely unused. The prices are comparable before and after
in the introductory period showing that the restraints were largely non-binding in the early period under the old Agreement. The changes in pricing are seen towards the end of the old restraint period in the following year. Retailers started discounting prices in spring of the following year under the new Agreement, when restraints were completely lifted. That shows that the old Agreement was mainly effective in keeping prices high towards the end of the restraint period. It is also evidence of dynamics in the pricing incentives over the course of the lifecycle. Thirdly, prices fall to about the same level at the clearance sale. The industry is seemingly not serving new groups of lower valuation consumers under the new Agreement by dropping prices deeper than before. On the contrary, it seems that the same consumer groups are served, but at different prices over the course of the lifecycle.

The changes in the price paths are not well explained by the standard theories of RPM. For instance, if double marginalization had been a first order issue, the price levels in the introductory period would be expected to increase under the new Agreement, yet they largely stay put. If the main effect of the old Agreement was to coordinate price competition between retailers, the introductory period price levels would expectedly drop. Moreover, the fact that price levels hardly change between the two Agreements in the introductory period suggests that competition between retailers is modest.

Figure 4 plots the corresponding shares of sales over the lifecycle. Note that the prices in the introductory period were comparable before and after the legislation change. The changes to prices came towards the end of the following year when the restraints were completely lifted. Demand is however seen to shift from comparable early lifecycle prices towards lower future prices under the new Agreement.

The evidence is consistent with forward looking consumers who changed their expectations after the new Agreement. Expecting lower future prices, consumers may be more willing to wait for a future discount at otherwise comparable prices. More demand is served at lower prices over the course of the lifecycle. These patterns in both price and demand patterns are qualitatively stable across years and across genres, see Figures 12 and 13 in the Appendix for the sales broken down over years. Whereas the pricing strategies are similar across titles, there is more variation in the demand responses across years.

### Table 2: Changes to introductory prices.

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5 Model setup

The goal of the empirical analysis is to quantify the commitment value of the old Agreement. While the old Agreement could provide commitment to future prices, it
also precluded retail price competition. To separate the effect of commitment from the effect of restricting retailer price competition, I turn to counterfactual exercises.

The modeling approach follows two steps. In the first step, substitution patterns along the horizontal and intertemporal dimension are estimated from the sales data. Consumers with unit demand make purchase decisions considering the current states and prices and their beliefs about future prices. These beliefs depend on the the vertical restraints in the market, such as if there is a fixed price agreement in place or not.

In the second step, a dynamic oligopoly model is used to evaluate the profitability of counterfactual vertical contracts. The contracts vary with the level of commitment and price coordination they offer. The oligopoly model is evaluated at the parameters estimated in the first step. The oligopoly model has a forward-looking demand side and a forward looking supply side. On the supply side, a publisher decide on the retail price restraints. Within the limits of the price restraints set by the publisher, the retailers set prices taking into account the impact of their prices on both the current and the future demand.

5.1 Market

Demand is represented by a finite horizon, discrete choice, adoption model with discrete, unobserved type heterogeneity. The finite horizon model allows for non-stationary pricing strategies, such as the fixed price agreements, and since the typical life cycle of a title is relatively short.

Each title is assumed to be an independent market. The assumption restricts substitution to be between retailers and over time for a given title, which is the central focus of this paper, but assumes away substitution between titles. The independent market assumption is strong, but hard to relax. Firstly, with many titles and relatively few periods of observations, there is limited variation in the data to estimate patterns of substitution between titles. Secondly, substitution between titles leads to a high dimensional state space that complicates the computation of value functions. Though the inclusive value sufficiency assumption of Melnikov (2013) can collapse the state space to a manageable dimensionality, it imposes strong restrictions on the state transitions.

The market for each title consists of one publisher, $J$ retailers, and a large, but finite number of $M$ heterogenous and forward looking consumers. Each title is introduced prior to period 1. The periodization of the model follows the four month periodization in the data. A market lasts for $T$ periods, where $T$ is between 7 and 9, i.e. the maximum lifecycle is 3 years. After the $T$th period, the market ends and no further transactions are made.

5.2 Consumers

At the start of the first period, there are $M$ consumers in the market. Consumers, indexed by $i$, either purchase from one of the $J$ retailers, or wait until the next period.
The choice set is denoted $\mathcal{D} = \{0, 1, \ldots, J\}$, where $\{0\}$ is the choice to not purchase from any of the retailers. If a purchase is made, the consumer leaves the market never to return. A consumer that chooses to wait faces the same choice set in the next period.

The product characteristics that are observable to the econometrician are prices at all retailers $p_t = [p_{1,t}, \ldots, p_{J,t}] \in \mathbb{R}^J$ and product and market characteristics $x_{j,t} \in \mathcal{X} \subseteq \mathbb{R}^K$ for all $j \in \mathcal{D}\{0\}$. The product characteristics include deterministic functions of time, such as seasonality and tastes for novelty, and time invariant characteristics, such as retailer fixed effects.

One state variable is which type of fixed price agreement is in the market. By assumption, this state variable enters the information set, but not the utility, and is assumed to be commonly known in the market. The assumption implies that the value of a given title to a consumer does not depend on the fixed price agreement in the market, but that the fixed price agreement affects consumers expectations about the future prices of the title. A change in expectations over future prices caused by the change in the agreements is central to the identification of forward-looking behaviour. The assumption that consumers knew of a change in pricing strategies is supported by the massive media attention the new Agreement received at the time.

All product characteristics, including prices, are assumed commonly observed in every period. A full description of the product characteristics is given in Section 8. This is a strong assumption about the consumers information set, but analytically highly convenient.

Each consumer privately observes a vector of utility shocks $\epsilon_{i,t} \in \mathbb{R}^{J+1}$ in each period prior to making the choice. The private utility shocks are drawn from an absolutely continuous distribution, independently of of the observable states. There are two types of consumers, indexed by $l \in \{1, 2\}$ with probability mass $m_l$ and $1 - m_l$, respectively. The current period utility of a consumer of type $l$ choosing option $j$ in period $t$ is $u^l_{j,t}(p_{j,t}, x_{j,t}, \epsilon_{i,j,t}) = u^l_j(p_{j,t}, x_{j,t}) + \epsilon_{i,j,t}$, additively separable in the observable states and the private shocks.

A consumer who purchases a title at any of the $J$ retailers collects utility $u^l_j(p_{j,t}, x_{j,t}) + \epsilon_{i,j,t}$ and leaves the market never to return. A consumer of type 1 that chooses to wait collects a current period utility normalized to zero, so

$$u^1_{j,t}(p_{j,t}, x_{j,t}, \epsilon_{i,j,t}) = \begin{cases} u^1_j(p_{j,t}, x_{j,t}) + \epsilon_{i,j,t} & \text{if } j \geq 1 \\ \epsilon_{i,0,t} & \text{if } j = 0. \end{cases}$$

The normalization of the utilities is standard, but not innocuous in dynamic models. The implications of the normalization for counterfactual choice probabilities are discussed in Section 6 on identification.

Consumers are assumed to form rational expectations over the state evolution given their information sets $I_t$. The information set includes all variables that affect the
consumers utility and expectations in period $t$. The expected future utility streams are discounted by a constant factor $\beta$, which is assumed equal across consumers. In each period, a consumer makes a choice $d \in D$ to maximize the expected lifetime utility.

$$V^i_t(p_t, x_t, \epsilon_{i,t}) = \max_{j \in D} \{ u^j_{j,t}(p_{j,t}, x_{j,t}) + \epsilon_{i,j,t} + \beta E[V^{i}_{t+1}(p_{t+1}, x_{t+1}, \epsilon_{i,t+1})|I_t] \} \quad (1)$$

The choice specific value function $v^j_{j,t}: \mathcal{X} \to \mathbb{R}$ gives the expected discounted lifetime utility, prior to learning $\epsilon_{i,t}$, of making choice $j$ in period $t$, and then choose optimally in the remaining periods.

$$v^j_{j,t}(p_t, x_t) = \begin{cases} u^j_{j,t}(p_{j,t}, x_{j,t}) & \text{if } j \geq 1 \\ \beta E[V^{i}_{t+1}(p_{t+1}, x_{t+1}, \epsilon_{i,t})|I_t] & \text{if } j = 0 \end{cases}$$

The choice probabilities are

$$Pr[d^i_{i,t} = j | p_t, x_t] = Pr[\epsilon_{i,t} : v^j_{j,t}(p_t, x_t) + \epsilon_{i,j,t} \geq \max_{k \in D} \{ v^k_{k,t}(p_t, x_t) + \epsilon_{i,k,t} \}]$$

The residual demand $R^1_t \in [0, 1]$ records the share of consumers of type 1 who are still in the market at time $t$. Assuming no sampling error, the type specific aggregate demand is

$$D^j_{j,t}(p_t, x_t, R_t) = R^j_{j,t} \cdot \max_{j \in D} \{ v^j_{j,t}(p_t, x_t) + \epsilon_{i,j,t} \}$$

The residual demand of type 1 is defined recursively

$$R^1_{t+1}(p_t, x_t, R_t) = R^1_t \cdot Pr[d^i_{i,t} = j | p_t, x_t]$$

with initial condition $R^1_1 = R^2_1 = 1$. The aggregate demand in period $t$ is the sum of the demand of the two types is

$$D_{j,t}(p_t, x_t, R_t) = m D^1_t(p_t, x_t, R^1_t) + (1 - m) D^2_t(p_t, x_t, R^2_t)$$

6 Identification

It is well known that the standard dynamic discrete choice models of Rust (1994) is non-parametrically underidentified. Magnac and Thesmar (2002) shows that without further assumptions, a static model can rationalize all choice data as well as any dynamic model. Conditional on the discount factor, Magnac and Thesmar’s Proposition 2 shows that a normalized utility function is identified. It is therefore common to fix the discount factor at an a priori plausible value. Since the consumers’ discount factor determines the profitability of the fixed price agreement in the model, assuming the discount factor assumes the conclusion, which seems unsatisfactory.

Common intuition suggests that if there is variation in the data that holds the cur-
rent payoffs fixed, but changes the continuation values, then the current period choice response to the change in continuation values is informative about time preferences. I first argue that the clear shift in the price paths that followed with the new Agreement may have changed consumers expectations of future prices and consequently their expected value of waiting for future discounts.

The introductory prices were approximately equal under the old and the new Agreement. The clear shift in demand in the year of publication is consistent with a change in the consumers’ beliefs about the future prices. Consumers who at the time of publication expected lower future prices under the new Agreement, may be more willing to postpone their consumption towards future discounts.

We can think of the transition from the old and the new Agreement as shifting price expectations, and hence the continuation value, without changing the consumption value of a purchase itself. Abbring and Daljord shows that this intuition can be formalized as exclusion restrictions that set identifies the discount factor. Specifically, if there exists a pair of states $x_{old}$ and $x_{new}$ such that the exclusion restriction

$$u_{i,t}(x_1) = u_{j,t}(x_2)$$

for some pair $i \in D, j \in D \setminus \{0\}, x_1, x_2 \in \mathcal{X}$ and $t \in 1, \ldots, t', t' \in 1, \ldots, T$, with either $i \neq j$, or $x_1 \neq x_2$, or $t \neq t'$, then the identified set is finite. With more than one such exclusion restriction, the intersection of the sets identified from each moment condition is assumed to be a point.

The assumption that the new Agreement in May 2005 came unexpected to consumers is more questionable. There was a lively debate in the media over the future of the old Agreement in the fall of 2004. To the extent consumers factored in a likely change to a new pricing regime with lower prices, it will bias the discount factor towards zero by attenuating the contrast between demand under the old and the new Agreement.

Following Abbring and Daljord, the auxiliary moment conditions derived under the exclusion restrictions in (3) are

$$\ln \left( \frac{s_{old,t}(p_{t},x_{t})}{s_{0,t}(p_{t},x_{t})} \right) - \ln \left( \frac{s_{new,t}(p_{t},x_{t})}{s_{0,t}(p_{t},x_{t})} \right) =$$

$$\sum_{\tau=t+1}^{T} \beta^{\tau-t} \left( E[\ln(s_{0,\tau}^{new}(p_{\tau},x_{\tau}))|I_{t}^{new}] - E[\ln(s_{0,\tau}^{old}(p_{\tau},x_{\tau}))|I_{t}^{old}] \right)$$

for $t = 1, \ldots, 3$ of the lifecycle in 2004 (old) and 2005 (new), for otherwise equal states $x_{t}$ and $p_{t}$, and for both consumer types, and where $j$ is taken to be a purchase of an inside good. Since there are no complete title level time series under the old Agreement, the moment conditions are constructed using the aggregate data in Section 4.

The price expectations are estimated separately under the old and the new Agreement. Under the old Agreement, there is little variation in prices, so price expectations are
set equal to the fixed price in the restraint period and the average sales price at the expiration of the restraint period. For the title level data under the new Agreement, the price expectations are estimated from the observed price transitions under the new Agreement. We can think of the discount factor as informed by data on changes in demand between the old and the new Agreement holding price fixed, while the utility function is estimated from the lifecycle demand under the new Agreement. The auxiliary moment conditions are added to the criterion function.\footnote{Abbring and Daljord shows that in a single agent model without latent types, the discount factor can be estimated independently of the utility function from the auxiliary moment condition. With latent types, as in the current model, the discount factor however must be estimated jointly with the full parameter vector.}

Kasahara and Shimotsu (2009) shows that two latent consumer types are non-parametrically identified for $T \geq 3$ with type independent transitions and some mild regularity conditions on the covariates which are plausibly met in the data. Market prices are commonly thought of as being determined simultaneously with demand in observational data. The most common solution to the endogeneity problem is to find instruments that are correlated with the retailers price incentives, but do not directly cause demand itself. Standard sources of instruments include marginal cost shifters (Working (1927)), variation in the density of the product space (Berry et al. (1995)), and common components in geographical price variation (Hausman (1996), Nevo (2001)).

These instruments are unfortunately either weak, questionable, or unavailable in this application. For books, marginal costs are likely close to constant over the lifecycle of a title, non-price product characteristics are mostly time-invariant, and there is no geographical variation in the data. As pointed out in Rossi (2014), instruments may under these circumstances cause more problems than they solve. The prices are therefore left to instrument for themselves. To alleviate a possible downward bias in the price sensitivity estimates in the absence of instruments, the price elasticities are restricted to be larger than one in absolute value. The restriction imposes a weak form of profit maximization in the demand estimation and is motivated by observing finite prices in the data.

From Magnac and Thesmar’s Proposition 2, the utility function is non-parametrically identified only up to a normalization of an arbitrary reference choice. Kalouptsidi et al. (2016) shows that a large class of counterfactuals are not identified in dynamic discrete choice models when the utility of the reference choice is normalized, but not identified, i.e. the standard case. The counterfactuals I consider changes the transitions which belong to the non-parametrically underidentified class.

Kalouptsidi et al. considers identification of counterfactuals under parametric assumptions on the utility function. Its Corollary 10 shows that when the counterfactual changes the transition process for state variables that are part of the identified component of the utility function, counterfactual choice probabilities are identified. In our case, the counterfactuals change the price transition and the price effects are parametrically identified. The counterfactuals are hence identified if we are willing...
to assume that the parametric specification in the demand model is the true model. Hence, the counterfactuals are identified under stronger assumptions than the discount factor and the utility function.

7 Specification and data selection

The data for the demand estimation are selected as all new fiction and non-fiction titles with strictly positive sales at all retailers for consecutive periods. There is substantial heterogeneity in sales between titles, both in volume and lifecycle demand distribution, which suggests using fixed effects at the title level. Title level fixed effects however come with two problems. Firstly, fixed effects imply thousands of free parameters in this application, which is computationally prohibitive. Secondly, with at most nine periods observed per title, fixed effects introduce incidental parameter bias.

It is common to discretize heterogeneity as a finite sample approximation to unrestricted heterogeneity. Such grouped fixed effects generally suffer from approximation bias. I use the two-step estimator Bonhomme et al. (2017) which trades off the incidental parameters bias of title level fixed effects against approximation bias of group fixed effects using a data driven, two-step, bias reduction approach. Bonhomme et al. shows that the estimator has desirable asymptotic properties when the underlying dimensionality of the heterogeneity is low, which is the case in this applications.

The estimator classifies the titles into groups using a $k$-means classifier in a first step and uses a bias reducing estimation procedure in a second step. The first step classifier is based on title specific moments of the data, $h_i$, that are informative about the heterogeneity. Let $\varphi(\alpha_{i,0})$ be the population value of $h$ at the true individual specific vector $\alpha_{i,0}$, where $\varphi$ is an unknown, injective function.

Given a number of $K$ groups, the groups are determined by minimizing a mean square criterion $\hat{Q}(K)$ as

$$
\hat{Q}(K) = \min_{h^{K_i}(k^K_i)} \frac{1}{N} \sum_{i=1}^{N} (h_i - h^K_i(k^K_i))^2
$$

where $k^K_i$ is a group membership indicator and $h^K_i$ is the group moment.

The number of groups $K$ is chosen trading off approximation bias against incidental parameter bias using the classifier

$$
\hat{K} = \min_{K \in \{1, \ldots, N\}} K \text{ s.t. } \hat{Q}(K) \leq \xi \hat{V}_h
$$

where $\hat{V}_h$ is a consistent estimator of the asymptotic variance

$$
\text{plim}_{N,T \to \infty} \frac{1}{N} \sum_{i=1}^{N} T_i (h_i - \varphi(\alpha_{i,0}))^2
$$
and $\xi$ is a tuning parameter set to 3.

The observable states are \( \{p_{i,t}, r_j, t, ssn_t\} \), where $i$ indexes the title, $j$ the retailer, $k$ the group, and $t$ indexes time. The utility specification is

$$u_{i,j,k,t}^l = \alpha^l + \alpha^l p_{j,k,t} + \alpha^l k + \gamma^k + \gamma^k t + \gamma_j r_j + ssn_t \gamma_{ssn} + \epsilon_{i,j,t}. \quad (4)$$

The parameter $\gamma^k$ is a group fixed effect and $r_j$ is a retailer fixed effect. Following Einav (2007) and Ho et al. (2012), the utility has a component $\gamma^k t$ that represents a group specific taste for novelty, where $t$ is a linear time trend. Retailer fixed effects are $\gamma_j r_j$, and seasonal fixed effects are $\gamma_{ssn} ssn_t$. The type specific parameters are superscripted by $l$. The utility parameters $\alpha$, $\gamma$ and $\beta$ are estimated with full solution methods using a minimum distance criterion.

The bias reduction step in Bonhomme et al. is implemented by first estimating the parameters $\hat{\theta}$ with group fixed effects on the full sample. Then $\hat{\theta}_1, \hat{\theta}_2$ are estimated on randomly selected halves of the sample, respectively, where the groups are held fixed in each sub-sample. The bias-reduced estimate is $\hat{\theta}^{BR} = 2\hat{\theta} - \hat{\theta}_1 + \hat{\theta}_2$. Standard errors are calculated by block bootstrapping, where the classifications are again held fixed in bootstrap samples.

The consumers are assumed to have rational expectations such that their expectations coincide with the true transition distribution. A consumer’s information set is $I_t = \{p_t, x_t, \epsilon_t\}$. All observable, non-price characteristics $x_t$ are deterministic with trivial transition distributions. The relevant transition probability distribution can therefore be written $F_t(p_{t+1}, \epsilon_{t+1}|I_t) = F_t(p_{t+1}|p_t, x_t) G(\epsilon)$, where $G$ is identified iid EV1 by assumption. The conditional distribution $F_t(p_{t+1}|p_t, x_t)$ is estimated from the observed state transitions by FGLS first step. The expectations are estimated separately under the old and the new Agreement as described in Appendix B. The model fits fairly well with $R^2 = 0.97$ for the expectations under the new Agreement. Following the arguments in Skrainka and Judd (2011), quadrature is used to numerically integrate out the expectations in the demand functions. I use the SparseGrid package of Heiss and Wincsel (2008) for the quadrature.

### 8 Estimation results

The parameter estimates are given in Table (3). The consumers discount factor $\beta$ comes out at 0.780, substantially less than the real interest rate which is used as the retailers discount factor. The estimated discount factor is lower than implied by the real interest rate, but higher than e.g. Dubé et al. (2014). There is some variation in retailer fixed effects, reflecting that the retailers are differentiated. While fall is the prime season where most titles are introduced, the fall fixed effect is negative. The negative fixed effect reflects that long tailed sales distribution. Though aggregate sales are higher in fall, the higher sales are distributed across more titles. In spring and summer, the sales is concentrated on fewer titles.
Table 3: Parameter estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type 1 Coeff</th>
<th>Std Err</th>
<th>Type 2 Coeff</th>
<th>Std Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.780</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>summer</td>
<td>-0.166</td>
<td>0.129</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fall</td>
<td>-0.300</td>
<td>0.138</td>
<td></td>
<td></td>
</tr>
<tr>
<td>retailer B</td>
<td>-1.039</td>
<td>0.254</td>
<td></td>
<td></td>
</tr>
<tr>
<td>retailer C</td>
<td>-0.110</td>
<td>0.093</td>
<td></td>
<td></td>
</tr>
<tr>
<td>retailer D</td>
<td>-0.826</td>
<td>0.103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$w$</td>
<td>0.215</td>
<td>0.178</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Retailer A is the base level

Group fixed effects: yes

Nr of groups: 5

Type specific parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type 1 Coeff</th>
<th>Std Err</th>
<th>Type 2 Coeff</th>
<th>Std Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>1.333</td>
<td>3.694</td>
<td>-0.132</td>
<td>2.684</td>
</tr>
<tr>
<td>$\alpha_p$</td>
<td>-1.112</td>
<td>0.913</td>
<td>-3.780</td>
<td>1.448</td>
</tr>
</tbody>
</table>

N: 40388

Figure 5 plots the own price elasticities, averaged over retailers and titles, against time.

![Figure 5: Own price elasticities](image)

9 The commitment value of the old Agreement

There is a limit to what can be learned about the price coordination effects of the old Agreement directly without data on the vertical contracts themselves. While the terms of the old Agreement are publicly known, the vertical contracts the industry switched to following the new Agreement are not known.
Instead, I ask what the estimated demand can say about the scope for both intrabrand price coordination and intertemporal price coordination. I take the commitment value of the Agreement (FPA) to be the profitability the fixed price agreement generates relative to two alternative contracts. In particular, the performance of the FPA contract is compared to a standard linear contract (NC), i.e. a time invariant wholesale price which offers no price coordination, and to one which coordinates the retailer pricing (HC) without commitment. For reference, the FPA contract is compared to a vertical price restraint that holds with commitment for all periods (FC). The FC contract serves as an upper bound to the returns to both commitment and intrabrand price coordination. The four contracts are described in detail below.

The profitability of the counterfactual contracts are evaluated in a dynamic equilibrium model with a forward-looking supply side and a forward-looking demand side, where rational price expectations are formed endogenously on both sides of the market. The outcomes of interest are the lifecycle price paths and profitability for a typical title across the hypothetical contract types.

The supply side has one publisher that supplies \( J \) retailers, where \( J = 4 \). The terms of sale, including restraints on retailers pricing, are regulated by contracts between the publisher and the retailers. Whereas the vertical contracts employed in the industry emerge from a complex and unobserved bargaining process between retailers and publishers, I make several simplifying assumptions to abstract from the bargaining process and instead focus on the profitability of the contracts to the vertical unit.

The division of profits between publishers and retailers is not explicitly modeled. A contract will therefore for our purposes be summarized by a set of retail price restraints. All contracts are assumed to be enforceable, which is known to the consumers, hence all commitment is credible. The commitment to the fixed price agreement is by assumption and not explicitly modeled as e.g. incentive compatible. The assumption of enforceable contracts is supported by the Agreement, which specified sanctions. The data in Section 4 show that deviations from the fixed prices were negligible.\(^{11}\)

Following Matthewson and Winter (1984), the HC and the FPA contracts are assumed to include a sufficient number of instruments, such as quantity independent transfers, to achieve the vertically integrated profits, given the contract type.\(^{12}\) The publisher and the retailers are assumed to agree on the contract terms, which include price restraints and transfers, that maximize the vertical units profits, but the non-price terms are left unmodeled.

\(^{11}\)There are however no publicly known instances of sanctioning of deviations, perhaps because the deviations were so modest.

\(^{12}\)One example of such transfers is known as 'marketing support', where a publisher pays the retailer a fixed fee for what may or may not be related to marketing activities.
9.1 Publisher and retailers

The equilibrium price restraints and retailer pricing strategies are solved as dynamic games. The publisher chooses price restraints \( p^F_t \), uniform across retailers. The price restraint dictates the retail price, i.e., it is both a ceiling and a floor. Though the optimal price restraints retailers would vary across retailers, I focus on price restraints that are uniform across retailers as these are the empirically relevant.

From the assumption that the commitment afforded by the price restraints is credible, there are no deviations from price restraints in the restraint period. The assumption is largely supported by the data, which showed only modest deviations from the price restraints.

Since all the observable, exogenous states \( x_t \) are deterministic, the dependence of \( D_{j,t} \) on \( x_t \) is suppressed in the following. Retailer \( j \)'s per-period profits depends on both its own prices \( p_{j,t} \) and its rivals prices \( p_{-j,t} \). A retailer's per-period profit function is

\[
\pi_{j,t}(p_{j,t}, p_{-j,t}, w, R_t) = (p_{j,t} - w)D_{j,t}(p_t, R_t)
\]

where \( w \) is the per unit wholesale price. The expected present value of profits to retailer \( j \) in period \( t \) is

\[
E_t \left[ \sum_{t=1}^{T} \rho^{t-1} \pi_{j,t}(p_{j,t}, p_{-j,t}, R_t) \middle| p_t, R_t \right].
\]

where \( \rho \) is the discount factor of the firms, which is assumed equal across retailers.

A price strategy profile is a set of of retail price strategies \( \sigma_t = [\sigma_{1,t}, \ldots, \sigma_{J,t}] \). A sequence of strategy profiles is denoted \( \sigma_\tau = \{\sigma_{1,t}, \ldots, \sigma_{J,t}\}_{t=\tau}^T \), for \( \tau = 1, \ldots, T \). Both retailers and the publisher form rational expectations \( F_t(R_{t+1} | \sigma_t, R_t) \) over the evolution of the pay-off relevant states, which is the vector of residual demands \( R_t \).

The consumer demand \( D_t(p_t, R_t) \) is as given in Section 5.1, with the exception that consumers form rational price expectations endogenously in the counterfactual analysis. The primitives that enter the counterfactuals are the utilities \( u \), the consumers’ and the firms’ discount factors, \( \beta \) and \( \rho \), respectively, and the cost structure, summarized by the constant marginal cost \( c \). The marginal cost is taken to be known and set to 10% of the introductory retail price, in line with industry estimates. While \( \beta \) is estimated from the demand data, \( \rho \) is set equal to \( \frac{1}{1+r} \), where the interest rate \( r \) is set to 2%, approximately the risk free interest at the time. The endogenous objects are the price strategies \( \sigma \), demand \( D_t(p_t, R_t) \), and expectations \( F_t(R_{t+1} | \sigma_t, R_t) \).

9.2 No Coordination

The publisher has no price coordinating role in the NC contract. In each period \( t \), the retailers set prices simultaneously after observing \( R_t \) the state of demand left in the market. The wholesale price \( w \) is set equal to \( c \), the marginal cost to the vertical
unit. The timing is illustrated in Figure 6.

<table>
<thead>
<tr>
<th>Period 0</th>
<th>Period 1</th>
<th>Period 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products introduced.</td>
<td>States $R_1$ commonly observed.</td>
<td>States $R_2$ commonly observed.</td>
</tr>
<tr>
<td>Retailers simultaneously and unilaterally set $p_1$.</td>
<td>Consumers observe $p_1$ and learn $\epsilon_1$.</td>
<td>Demand $D_1$ realized.</td>
</tr>
<tr>
<td>Consumers observe $p_1$ and learn $\epsilon_1$.</td>
<td>Demand $D_1$ realized.</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6: Timing No Coordination**

The price strategies $\sigma_t$ are Markov, i.e. they map the current, pay-off relevant states to prices. A sequence of strategies for retailer $j$ is written $\sigma_j, t = \{\sigma_j, \tau\}_{\tau=t}$. The value function $\Pi_{j,t}$ gives each retailer’s net present value of profits as of time $t$, conditional on the strategy profile $\sigma_t = [\sigma_1, t, \ldots, \sigma_J, t]$, and is given as

$$
\Pi_{j,t}(R_t; \sigma_{j,t}, \sigma_{-j,t}) = \pi_{j,t}(\sigma_{j,t}, \sigma_{-j,t}, R_t) + \\
\rho \int \Pi_{t+1}(R_{t+1}; \sigma_{j,t+1}, \sigma_{-j,t+1}) \times \\
dF(R_{t+1}|\sigma_{j,t}, \sigma_{-j,t}, R_t)
$$

for all $j \in 1, \ldots, J$ and $t \in 1, \ldots, T$.

The solution concept is Markov Perfect equilibrium. A solution is a sequence of strategy profiles $\sigma^NC_1 = (\sigma_1, \ldots, \sigma_J)$ such that for all retailers, in every period, the equilibrium condition

$$
\Pi_{j,t}(R_t; \sigma^NC_{j,t}, \sigma^NC_{-j,t}) \geq \Pi_{j,t}(R_t|\sigma'_{j,t}, \sigma^NC_{-j,t})
$$

holds. The condition implies that each retailer $j$ prefers $\sigma^NC_{j,t}$ to any alternative sequence of Markov strategies $\sigma'_{j,t}$, conditional on its rivals pricing according to $\sigma^NC_{-j,t}$, in any period. The resulting price strategies are hence time-consistent for each retailer.

An $NC$ equilibrium is a fixed point where prices are set according to $\sigma^NC_1$ in every period, demand follows from section 5.1, and the price expectations of retailers and consumers are consistent with the pricing and demand.

### 9.3 Horizontal Coordination

Under the $HC$ contract, the publisher coordinates the intrabrand retail pricing. After having observed the current pricing relevant states $R_t$, the publisher sets price restraints $p^F_t$ in each period and uniform across retailers. The restraint is revised in every period to optimize the expected present value of joint profits to the vertical unit. The timing is illustrated in Figure 7.

The equilibrium restraints are the price strategies that maximize the net present value joint profits of the vertical unit, taking into account that in the next period, the restraints will again be set with the same objective, i.e. the strategies are time
consistent. The relevant marginal cost for the vertical unit is the marginal cost of production \( c \). The \( HC \) strategies is a fixed point such that

\[
\sigma^HC_t = \arg \max_{p \in \mathbb{R}_+} \sum_{j=1}^{J} \pi_{j,t}(p, p, R_t, c) + \sum_{j=1}^{J} p \int \Pi_{j,t+1}(R_{t+1}; \sigma^HC_{t+1}) dF(R_{t+1}|R_t)
\]

holds for all \( t \in 1, \ldots, T \). Though I abstract from the implementation, it could be by a dynamic two-part tariff where the publisher in each period sets a wholesale price \( w_t \) such that no retailer unilaterally has an incentive to deviate from \( \sigma^HC_t \).

### 9.4 FPA

In period 1, the publisher sets a fixed retail price \( p^F \), which is constant over the restraint period and uniform across retailers. The restraint period is set to four periods, corresponding to the modal title in the data being released in fall. The fixed price \( p^F \) is set to maximize the expected profits of the vertical unit given the first period information set, taking into account that following the restraint period, retailers will unilaterally set prices in every period, without commitment, i.e. use \( \sigma^{NC}_t \) for \( t > 4 \). In the non-restraint periods, the retailers price incentives depend on the wholesale price \( w \). The timing is illustrated in Figure 8.

---

**Figure 7:** Timing Horizontal Coordination

**Figure 8:** Timing FPA

---

\(^{13}\)The marginal cost of retail is assumed to be zero.

\(^{14}\)Rather than explore a more complex contract with temporal variation in the wholesale price in the non-restraint period, I fix the wholesale price to \( c \) in all periods.
The fixed price restraint solves

\[ p^F = \arg \max_{p \in \mathbb{R}_+} \mathbb{E}_1 \left[ \sum_{j=1}^J \sum_{t=1}^4 \rho^{t-1} \pi_{j,t}(p, p, R_t) | R_1 \right] + \rho^4 \mathbb{E}_1 \left[ \sum_{j=1}^J \Pi_{j,5}(x_5, R_5 | \sigma^{NC}_5, R_4) | R_1 \right] \]

for all \( j = 1, \ldots, J \), and where \( \sigma^{NC}_j \) satisfies (5) for each retailer in the periods after the restraint period expired, i.e. \( t = 5, \ldots, 7 \). The FPA strategies are hence

\[ \sigma_{j,t}^{FPA} = \begin{cases} p^F & \text{if } t \leq 4 \\ \sigma_{j,t}^{NC} & \text{if } t > 4 \end{cases} \]

### 9.5 Full Commitment

The \( \sigma^{FPA} \) strategy offers commitment only during the restraint period. It is suboptimal in that it is constant over the course of the restraint period and it does not provide price coordination towards the end of the lifecycle. As a benchmark, I calculate a strategy \( \sigma^{FC} \) where the publisher sets the price restraints with commitment in the first period and with full compliance by retailers. Consumers learn the price path at the announcement in the first period which removes any uncertainty over future prices. The timing is illustrated in Figure 9.

**Figure 9:** Timing Full Commitment

The commitment strategy maximizes the expected present value of the joint profits of the vertical unit (retailers plus manufacturer) as of the first period

\[ \sigma^{FC} = \arg \max_p \sum_{j=1}^J \sum_{t=1}^T \rho^{t-1} \mathbb{E} \left[ \pi_{j,t}(p, p, R_t) | R_t \right] | R_1 \]

The strategy is time-inconsistent, i.e. in any period \( t \), the vertical unit, as well as each individual retailer, has an incentive to deviate from the strategy.

### 10 Counterfactual results

The equilibrium contracts are calculated at the estimated demand parameters and at the mean of the exogenous states \( x \) in the sample. The results can be interpreted as the equilibria contracts for a typical title which is released in fall in the year of introduction. The typical title has a lifecycle of seven periods, where the periodization in the model follows the periodization in the data.

For each contract type, the price strategies described in Section 9 are calculated along
with the corresponding demand and profits. To maintain anonymity of the retailers, the reported prices and demand are averaged over the retailers. There is substantial heterogeneity in demand across titles. In the data, about 2% of the titles make up about 50% of the sales. I therefore calculate the contracts for two types of titles: a typical title and a bestseller. The title types correspond to the group fixed effects. A typical title is calculated at the average fixed effects, while the bestseller counterfactual is calculated at the fixed effects for the bestsellers.

The equilibrium price and demand paths for a typical title are plotted in Figure 10. We first note that the full commitment $FC$ price path declines over the lifecycle. The declining price path under $FC$ seems to contradict Stokey (1979)’s result which shows that the monopolist commitment path is constant and equal to the static monopoly price. The difference follows from different assumptions. In Stokey, the consumers and the monopolist have the same discount factor, whereas here, the consumers have a lower discount factor than the retailers. The relative impatience of consumers in this application allows the vertical unit some room to price skim with commitment without seeing too much demand substitute to future prices. If consumers and publishers have equal discount factors in the model, the $FC$ price path is indeed constant. Since there is no uncertainty in the demand in the model, the $FC$ contract is the most profitable of the four contracts.

The $HC$ price path displays two important features: the introductory price is about the same as in $FC$, but without commitment, the prices unravel. In $HC$, the publisher acts on the incentive to lower the price as higher valuation consumers clear out of the market. Expecting these lower future prices, the consumers are more reluctant to purchase early than they would be at the same price under $FC$. The terminal $HC$ price is lower than the terminal $FC$ price, which implies that there is less rationing under $HC$. In contrast, the later $FC$ prices are higher than $HC$ not to raise profits late in the lifecycle, but to persuade consumers to purchase early at high prices. Convincing consumers to purchase early comes at the cost of rationing consumers with willingness to pay in excess of the costs.

In the $NC$ equilibrium, retailers set prices unilaterally without commitment. Two features of the $NC$ strategy stand out. Firstly, due to price competition between retailers, the introductory price level drops relative to the $FC$, $HC$, and $FPA$ strategies. Secondly, the $NC$ price path flattens out relative to $HC$, reflecting that retailers with less market power individually find more limited scope for price skimming than a single publisher that controls the retailers’ wholesale price.

The introductory price under the $FPA$ contract stays at a level similar to the $FC$ contract for the four restraint periods (the typical title is assumed introduced in fall and remain price restrained throughout the following year), after which the retailers set prices unilaterally for the remainder of the lifecycle, i.e. they follow the $NC$ strategies. After the expiration of the restraint period, the $FPA$ prices fall to a level marginally higher than under the $NC$ contract. The similarity in introductory prices between $HC$ and the $FPA$, and the difference to the $NC$ introductory price level,
shows that the *FPA* served to coordinate intrabrand price coordination. It however also shows that the intrabrand price coordination could be achieved by standard vertical contracts, like *HC*. The demand for the typical title is more evenly distributed over the lifecycle than the aggregate demand in Section 4. The discrepancies in part reflect that the aggregate data does not follow a particular title.

The profits of the *FC* contract in excess of the *HC* contract arrives early in the lifecycle as commitment leads to higher demand at otherwise equal prices. Later in the *FC* lifecycle, the higher *FC* generate less demand as the higher prices ration demand. The total profits of the three contracts relative to *HC* are given in Table 4. No vertical control decreases industry profitability by about 3.94%, while *FC* increases profits by 5.73% over the same baseline.

**Table 4: Relative counterfactual profits for a typical title**

<table>
<thead>
<tr>
<th>Contract</th>
<th>Percent change relative to <em>HC</em></th>
<th>Percent change relative to <em>NC</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>0</td>
<td>3.94</td>
</tr>
<tr>
<td>NC</td>
<td>−3.79</td>
<td>0</td>
</tr>
<tr>
<td>FC</td>
<td>1.72</td>
<td>5.73</td>
</tr>
<tr>
<td>FPA</td>
<td>−2.49</td>
<td>1.35</td>
</tr>
</tbody>
</table>

The *FPA* contract represents the old Agreement which fixed the retail price for four periods for a typical title, followed by retailers pricing the title at discretion after the restraint period expired. The equilibrium paths are plotted in Figure 10 and the profits are reported in Table 4. The profits of the *FPA* contract is seen to be lower than the *HC* profits. The price and demand patterns also differ substantially. The *FPA* achieves a higher degree of separation of consumers by keeping prices fixed early in the lifecycle. On the other hand, *FPA* serves more consumers at lower prices later in the lifecycle when it can not sustain a higher price level. As a consequence, *FPA* rations less than *FC*. Like for the observed prices, the *FPA* prices fall to a terminal price level comparable to both the *HC* and the *NC* levels.

It is not publicly known which type of vertical contracts the industry turned to after the legislation. The *NC* price paths show that without retail price coordination, the price paths would have flattened out and the introductory price levels would have dropped. The observed price skimming under the new Agreement in Figure 3 is more similar to the *HC* price path than the *NC* price path, which suggests that the industry shifted to some price coordinating vertical contracts. Under *HC*, the publisher can still coordinate the prices between retailers with a bilateral dynamic two-part tariff, but without commitment power, the prices unravel as consumers expectations of future discounts become self-fulfilling. Moreover, the *HC* contract in fact performs marginally better than the *FPA* contract, which offers commitment. The *FPA* contract is however not the optimal commitment strategy. The consumers are not patient enough for the returns to commitment under *FPA* to exceed the returns to price discrimination under *HC*. 
For bestsellers, the price paths of the four strategies follow the same qualitative pattern as for a typical title, but at higher price levels. The introductory prices under the counterfactual contract HC and FPA exceed the introductory prices in the data by about 10%, but generate approximately the same discount towards the end of the lifecycle (35%). Again, going from FPA to HC in fact increases the introductory price marginally, unlike in the data, but then HC prices unravel in lack of commitment.

The demand for the bestsellers follow a declining path over time more similar to the aggregate data in Figure 4. Under the FPA strategy, the model however predicts a demand increase at the expiration of the restraint period following from pent-up demand in the restraint period, which is not in the data. The price discount at the expiration of the restraint period under FPA is smaller than the price discount in the aggregate data, about 30% vs 40%, respectively.

The relative profits in Table 5 are more sensitive to the price strategies for the bestsellers. Though the FPA offers some price coordination, the coordinated price skimming strategy in HC dominates in terms of profits.
Figure 11: Equilibrium price, demand, and profits for the four contract types for a bestseller

10.1 Caveats

The supply side model is fairly stylized and makes a number of restrictive assumptions. One is that the value of commitment in models with discrete time depends crucially on the periodization. The periodization of the model follows the data sampling intervals, which are four months. Under a counterfactual contract like $NC$, the periodization still implies a piecewise commitment: once the retail price is set at the start of the period, the retailers are by assumption committed to that price throughout the four month period. In reality, there are no such constraints on the prices.

Table 5: Relative counterfactual profits for a bestseller

<table>
<thead>
<tr>
<th>Contract</th>
<th>Percent change relative to $HC$</th>
<th>Percent change relative to $NC$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>0</td>
<td>29.03</td>
</tr>
<tr>
<td>NC</td>
<td>$-22.50$</td>
<td>0</td>
</tr>
<tr>
<td>FC</td>
<td>$3.55$</td>
<td>$33.61$</td>
</tr>
<tr>
<td>FPA</td>
<td>$-9.79$</td>
<td>$16.40$</td>
</tr>
</tbody>
</table>
The periodization does not follow from evidence on how retailers actually set prices, but is an artifact of the data sampling. The retailers could change prices more frequently than every tertile. The model therefore likely overstates the profits of a no-commitment strategy. Without data on the actual frequency of price changes, there is a limit to how much can be done to ameliorate the problem. One robustness test is to carve up each four month period in shorter sub-periods, and allow the retailers to change prices in every sub-period. Such a robustness test is however hard to implement since the estimated demand parameters are not consistent with a finer periodization and more granular demand data are not available.

The simplicity of the FPA pricing rule, constant for the publication year plus the following year and uniform across retailers, was easy for consumers to understand and may have helped to fix the consumers’ price expectations. A consumer needed only see the current price and the year of introduction of a given title to accurately predict its price path. In contrast, title specific, dynamic price paths, like the FC path, which vary by title, and over time, require formation of much more complex expectations.

The demand model makes strong assumptions about both the retailers and the consumers information sets. Consumers have information on the prices at all stores, at all times, and form expectations based on their current information set, their perceptions of the residual demand in the market, and the state of competition in the market. One implication of the full information assumption is that the model leaves no room for a trade-off between the simplicity of the FPA pricing rule and the returns to price skimming. That level of information and rationality puts the FPA at a disadvantage relative to the optimal FC price strategy, that allows for some price skimming over the periods. Moreover, the model predicts fairly large differences in introductory prices between bestsellers and a typical title. Most titles within a genre is however introduced at the same price point, reflecting the unpredictable sales potential of individual titles.

The rigidity of the FPA strategy makes sense in a more realistic world where the retailers know more about local demand conditions than publishers, where there is uncertainty about the sales potential of a title, and where consumers have limited resources to form accurate expectations over future prices. By fixing the price early in the lifecycle to prevent unravelling, and then leave it to better informed retailers to clear out the inventory later in the lifecycle, the Agreement may have struck a balance between commitment and pricing flexibility. The trade-off between commitment and flexibility to adapt the pricing to demand uncertainty is not considered in the analysis, but is likely material.

The analysis abstracted from competition between publishers. Competition between publishers restricts the publishers ability to implement a price skimming strategy by vertical restraints. The effect of increased competition between publishers is therefore to reduce the value of commitment. Competition between publishers is particularly relevant in a market with vertical restraints where the market performance is determined largely by the competition in the upstream market, and not among retailers. A full analysis of competition between publishers would however require an analysis
of competition between titles, which has not been explicitly addressed here. However, beyond changing the form of the vertical restraints, the new Agreement did not have much impact on the structure of the upstream publishing market. The lack of impact on the competition between publishers may explain why the changes to the introductory prices were so limited.

Since the analysis of both the demand and the supply side rely on strong assumptions, the analysis should be considered an inquiry into dynamic effects of vertical restraints at empirically plausible values rather than an evaluation of the Norwegian fixed price agreement itself.

11 Discussion

The book industry’s united support for the old Agreement suggests that it solved a price coordination problem that its members could not solve by standard, bilateral vertical contracts like RPM and multi-part tariffs. The main difference between standard vertical restraints and fixed price agreement is that the Agreement commits the members of the industry to a particular price path.\(^\text{15}\) Still, the results in this paper still show that at the discount factor recovered from the data, the returns to more flexible price skimming offered by a dynamic two-part tariff, without commitment, exceed the returns to the commitment price strategy implied by the old Agreement. Such dynamic two-part tariffs are used in other markets for durable goods. Nair (2007) notes that dynamic two-part tariffs are used the video game industry to control the price paths in a competitive retail market.

The Norwegian book market is only one of many markets that has seen fixed price agreements abolished. The evidence from evaluations of abolishment is mixed, see Canoy et al. (2005), though to the best of my knowledge, none has studied the impact on of fixed price agreements on lifecycle pricing. The evidence from the change in the Norwegian Agreement stands in contrast to the evidence from the US e-book market which effectively adopted a fixed price agreement in the spring of 2010 when Apple and six of the largest publishers imposed the agency pricing model. Under the agency pricing model, the publishers set the retail price and leaves the retailer with a fixed percentage of the revenue, in this case 30%. Once the agency pricing model was instated in the US e-book market, the Department of Justice documented that the e-book prices levels immediately increased by about 20% in the spring of 2010.\(^\text{16}\). The mixed evidence across countries suggests that fixed price agreements serve a variety of purposes, where the dominant effects may vary between countries.

The prevalence of fixed price agreements in book markets is partly related to the relative ease with which the industry is allowed exemptions in jurisdictions where RPM is illegal, such as in the European Union. Markets for books are however not the only ones to adopt fixed price agreements. Collective adoption of RPM has emerged in

\(^{15}\) According to standard theories, both RPM and multi-part tariffs can achieve the same retail price targets, see e.g. Tirole (1988).

\(^{16}\) See https://www.justice.gov/atr/case/us-v-apple-inc-et-al
other markets for intellectual property in jurisdictions where RPM is legal, for instance like music (iTunes store) and software (AppStore).

12 Summary

This paper studies the dynamic effects of a fixed price agreement in a market for durable goods. When the price restraints of the old Agreement were weakened, the industry changed to a price skimming strategy. While vertical price restraints like RPM are usually thought of as restricting the retail price level, the changes in sales following following the new Agreement shows the price restraints restricted the price paths. In markets for durable goods where consumers strategically time their purchases, it is not a priori clear whether the Agreement restricted the industry from implementing more profitable price skimming strategies or if the prices unraveled without the commitment offered by the Agreement. Using parameters estimated using scanner level data from about half of the national market around the time of the new Agreement, the commitment effect of a fixed price agreement is quantified in a dynamic equilibrium model with forward looking demand and a forward looking supply side with a vertical structure. Given the modest consumer discount factor recovered from the sales data, the value of the commitment offered by the fixed price agreement is dominated by alternative vertical restraints that, without commitment, implements price skimming strategies.

References


Rossi, P. (2014). Even the rich can make themselves poor: A critical examination of iv methods in marketing applications. *Marketing Science* 33, 655–672. 15


A Calculating market shares

The market size must be estimated to calculate the market shares. The market size is estimated proportional to the maximum observed sales for a title in its genre. The proportionality factor is set to 1.5. Experiments with different constants show that the results are not particularly sensitive factors in the range from 1 to 2.

A.1 Changes in release dates

The release dates are from a data base provided by Bokbasen, a company that supplies the industry with information on titles. The data base is used for logistical purposes across retailers and publishers. The release dates are recorded as the time the publishers register a title in the logistical database. The results from regressing the tertile of release on a dummy for the new Agreement across titles are given in Table 6 and show virtually no differences. The median title is released in the second tertial under both the old and the new Agreement. The data are however known to have some measurement errors.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coeff</th>
<th>Std. Err.</th>
<th>Coeff</th>
<th>Std. Err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>after</td>
<td>0.003</td>
<td>0.014</td>
<td>-0.003</td>
<td>0.015</td>
</tr>
<tr>
<td>Intercept</td>
<td>2.063</td>
<td>0.013</td>
<td>2.082</td>
<td>0.036</td>
</tr>
<tr>
<td>Fixed effects</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>16605</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Change in introductory price levels before and after the new Regulation

B Estimation of the state transitions

Partition the observable, payoff relevant states in the stochastic and deterministic processes $I_t = (p_t, x_t)'$, respectively. The state transitions are assumed to follow the first order Markov process

$$I_{t+1} = \Theta I_t + \eta_t$$

for $t = 1, \ldots, T - 1$ where $\Theta$ includes retailer specific price coefficients. Partition the parameters $\Theta$

$$\Theta = \begin{bmatrix} \theta_{pp} & \theta_{px} \\ 0 & \theta_{xx} \end{bmatrix}$$

where the zero block in the lower left corner is a restriction on the parameters that follows from the exogeneity of $x$. By forward iteration, write as

$$I_{t+r} = \Theta^r I_t + \sum_{\tau=1}^{r} \Theta^{r-\tau} \eta$$
The shocks $\eta$ are assumed mean zero, multivariate normal, and serially uncorrelated. The moment conditions are

$$E[\eta_t|I_t] = 0 \text{ for all } t. \quad (6)$$

$$E[\eta_t\eta_t'|I_t] = \Sigma \text{ for all } t. \quad (7)$$

$$E[\eta_t\eta_{t+r}|I_t] = 0 \text{ for all } t \neq r. \quad (8)$$

The assumptions on $\eta$ jointly define a martingale difference sequence adapted to the observable information set $I_t$. The first two moments of the expectations conditional on $I_t$ are hence tractable functions of $I_t$ itself.

$$E[I_{t+\tau}|I_t] = \Theta^\tau I_t + \sum_{\tau=1}^{r} \Theta^{\tau-\tau} E[\eta_{t+\tau}|I_t]$$

$$= \Theta^\tau I_t$$

since $E[\eta_{t+\tau}|I_t] = 0$ for $\tau \geq 1$. Under assumptions (6)-(8), the second moment is

$$V[I_{t+\tau}|I_t] = V \left[ \sum_{\tau=1}^{r} \Theta^{\tau-\tau} \eta_{t+\tau} | I_t \right]$$

$$= \sum_{\tau=1}^{r} \Theta^{\tau-\tau} \Sigma \Theta^{\tau-\tau}$$

Normality along with rational expectations implies that the first two moments of the transition process completely describe the expectations. The distributions are assumed stationary, so $F_t(p_{t+1}|p_t, x_t) = F(p_{t+1}|p_t, x_t)$.

The transition process is estimated from the observed price series using a Seemingly Unrelated Regression with lagged prices. Stacking the price equations for each title $l$, we get

$$\begin{pmatrix}
    p_1 \\
    \vdots
    \\
    p_L
\end{pmatrix} =
\begin{pmatrix}
    \theta_{pp} p_1 + \theta_{px} x_1 \\
    \vdots
    \\
    \theta_{pp} p_L + \theta_{px} x_L
\end{pmatrix} +
\begin{pmatrix}
    \eta_1 \\
    \vdots
    \\
    \eta_L
\end{pmatrix} \quad (9)$$

where $lp$ are lagged prices. We now have standard linear system of equations that by reorganizing the parameters $\Theta$ can be written as

$$p = [lp, x] \Theta_{FGLS} + \eta \quad (10)$$

The estimation follows a two-step procedure. In the first stage, OLS is run on (10). The estimated covariance $\hat{\Omega}$ is

$$\hat{\Omega} = I_L \otimes \hat{\Sigma}$$
where $\hat{\Sigma} = \frac{1}{T} \hat{\eta} \hat{\eta}'$ is a consistent estimator of covariance. The FGLS estimator is now the familiar

$$\Theta_{FGLS} = \left( [lp, x]' \hat{\Omega}^{-1} [lp, x] \right)^{-1} [lp, x]' \hat{\Omega}^{-1} p$$

By standard arguments, the errors $\hat{\eta}$ are asymptotically normal with covariance $\hat{\Sigma}$.

The process is stable at $\hat{\Theta}$ with the characteristic roots of the price parameters all being of modulus less than one.

B.1 Descriptive evidence over years

Figure (12) shows that the price paths are fairly similar in all years following the deregulation. Prices start declining earlier under the new Agreement, but fall to about the same level. Similarly, the shift of demand from early at high prices to later at lower prices is also seen to be stable across the three years under the new Agreement, with some variation.

C Algorithms

The exogenous state variables $x_t$ are assumed commonly observed by both consumers, firms, and the analyst. For notational convenience, the dependence of the value functions on $x_t$, which all evolve deterministically, is suppressed and written as $v_{j,t}(p_t)$. The endogenous objects are the prices strategies $\sigma_t \in \mathbb{R}_{+}^J$, the demand of both types $D_1^t \in [0,1]^{J+1}$, $D_2^t \in [0,1]^{J+1}$, and the price expectations $F_t$. The games are all solved by backwards induction. The algorithm finds exact solutions on a grid of the state space and interpolates between.

The dynamics are driven by the option value of no-purchase, $v_{0,t}$. Since we consider Markov price strategies, the conditional expectations over future states are written as
expectations over the pay-off relevant states. The pay-off relevant states, beyond the deterministic states $x_t$, are the residual demands $R^e = [R^e_1, R^e_2] \in [0,1]^2$. Integrating out $\epsilon$ in closed form, the choice specific value function of the no-purchase option is

$$v_{0,t}(R_t) = \beta \int \ln \left( \sum_{j=0}^{J} \exp(v_{jt}(R_{t+1})) \right) dF_t(R_{t+1}|R_t).$$

Once the conditional expectations $F_t(R_{t+1}|R_t)$ are set, the demand $D_t$ and the residual demands $R_{t+1} = D_{0,t}$ are deterministically rolled over to the next period and hence $F_t$ is degenerate.

It is convenient to condition $v_{0,t}$ on an arbitrary, expected next period residual demand vector $R^e = [\hat{R}^e_1, \hat{R}^e_2] \in [0,1]^2$.

$$v_{0,t}(\hat{R}^e) = \beta \ln \left( \sum_{j=0}^{J} \exp(v_{jt}(\hat{R}^e)) \right) + \beta \varphi$$

where $\varphi$ is Euler’s constant. Then write the demand in terms of $v_{0,t}$ conditional on the current state $R_t$ and the expected future state $\hat{R}^e$:

$$D_t(\sigma_t, R_t, v_{0,t}(\hat{R}^e))$$

In a rational expectations equilibrium, the expectations are consistent with the residual demand they generate. A rational expectations equilibrium is then a pair of functions $R^e_1 : [0,1]^2 \rightarrow [0,1], R^e_2 : [0,1]^2 \rightarrow [0,1]$ that are the fixed points to the equilibrium conditions

$$D^1_{0,t}(\sigma_t, R_t, v_{0,t}(R_{t+1}(R_t))) = R^e_{1,t+1}(R_t) \quad (11)$$

$$D^2_{0,t}(\sigma_t, R_t, v_{0,t}(R_{t+1}(R_t))) = R^e_{2,t+1}(R_t)$$

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given the price strategies $\sigma$, which are described below. The simultaneous equations in (11) are solved at each grid point and interpolated between. Since the profits relevant to the analysis are those of the integrated vertical unit, wholesale prices are ignored. The marginal cost to the vertical unit is set to 0.2. The counterfactuals are computed at the sample averages of $x$.

**Horizontal Coordination algorithm**

The $HC$ algorithm is a multi product, monopolist pricing problem. Starting in period $T$, the algorithm solves for equilibria on a grid $R$ of $B$ points in $[0, 1]^2$, indexed by $b$, with typical element $R^b = [R_{1}^{b}, R_{2}^{b}]$.

**Period $T$:** For each point $R^b \in R$, solve

$$\sigma_T(R^b) = \arg \max_{\sigma \in \mathbb{R}^J_+} \Pi_T(\sigma, R^b)$$

$$= \arg \max_{\sigma \in \mathbb{R}^J_+} \sum_{j=1}^{J} (\sigma_j - c)D_{j,T}(\sigma, R^b, v_{0,T}())$$

1. For each guess $\sigma^0 = [\sigma_1^0, \ldots, \sigma_J^0]$
   - Set $v_{0,T}() = 0$, by normalization of the outside utility.
   - Calculate $\Pi_T(\sigma^0, R^b)$.

**Period $T-1$:** For each point $R^b \in R$, solve for

$$\sigma_{T-1}(R^b) = \arg \max_{\sigma \in \mathbb{R}^J_+} \Pi_{T-1}(\sigma, R^b)$$

$$= \arg \max_{\sigma \in \mathbb{R}^J_+} \sum_{j=1}^{J} (\sigma_j - c)D_{j,T-1}(\sigma, R^b, v_{0,T-1}(R^c)) + \rho \Pi_T(\sigma_T(R^c_T), R^c)$$

such that

$$D_{0,T-1}(\sigma, R^b, v_{0,T-1}(R^c)) = R^c$$

1. For each guess $\sigma^0$
   - Solve the system of equations $D_{0,T-1}(\sigma^0, R^b, v_{0,T-1}(R^c)) = R^c$ for the consistent expectations $R^c_T(R^b)$.
   - Calculate $\Pi_{T-1}(\sigma, R^b)$.

Roll back to the first period.

**No Coordination algorithm**

The $NC$ has the same structure as the $HC$, but adds an inner loop that in each period iteratively searches for an MPE in prices. The algorithm converges at the relevant range of parameters. See Section (9) for the timing of the game.

**Period $T$:** For each point $R^b$ in $R$, search for $\sigma_T = [\sigma_{1,T}^b, \ldots, \sigma_{J,T}^b]$ such that the best response condition

$$\sigma_{j,T}(R^b) : \pi_j(\sigma_{j,T}(R^b), \sigma_{-j,T}, R^b) \geq \max_{\sigma} \pi_j(\sigma, \sigma_{-j,T}, R^b),$$

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holds for all retailers \( j = 1, \ldots, J \).

1. Set \( v_{0,T}(R^b,.) = 0 \), by normalization of the outside utility.

2. For each guess \( \sigma^0 \), solve for the best responses

\[
\sigma_j^1 = \arg \max_{\sigma_j \in \mathbb{R}_+} \Pi_{j,T-1}(\sigma_j, \sigma_{-j}^0, R^b)
\]

\[
= \arg \max_{\sigma_j \in \mathbb{R}_+} (\sigma_j - c)D_{j,T}(\sigma_j, \sigma_{-j}^0, R^b, 0),
\]

sequentially or simultaneously for all \( j = 1, \ldots, J \).

3. Repeat until convergence in \( \sigma \).

**Period T-1:** For each point \( R^b \) in \( \mathcal{R} \), solve for the best responses

\[
\sigma_{j,T-1}(R^b) = \arg \max_{\sigma_j \in \mathbb{R}_+} \Pi_{j,T-1}(\sigma_j, \sigma_{-j}^0, R^b)
\]

\[
= \arg \max_{\sigma_j \in \mathbb{R}_+} (\sigma_j, T-1 - c)D_{j,T-1}(\sigma_j, \sigma_{-j}, T-1, R^b, v_{0,T-1}(R^c)) + \rho \Pi_{j,T}(\sigma_T(R^c), R^c)
\]

such that

\[
D_{0,T-1}(\sigma_{T-1}, R^b, v_{0,T-1}(R^c)) = R^c
\]

for all \( j = 1, \ldots, J \).

1. For each guess \( \sigma^0 \)

\(
\rightarrow \) Solve the system of equations \( D_{0,T-1}(\sigma^0, R^b, v_{0,T-1}(R^{c,0})) = R^{c,0} \) for consistent expectations \( R^{c,0}(R^b) \).

\(
\rightarrow \) Calculate \( \Pi_{j,T-1}(\sigma^0, R^b) \) for all \( j = 1, \ldots, J \).

\(
\rightarrow \) Update the best response \( \sigma_j^1 \) sequentially or simultaneously for all \( j = 1, \ldots, J \).

2. Repeat until convergence in \( \sigma \).

Roll back to period 1.

**Fixed Price Agreement algorithm**

The *FPA* algorithm solves for the equilibrium to effectively a two-period game. In the first period, the publisher decides on a price restraint \( p^F \) which holds for four periods. Following the expiration of the restraint period, the retailers use *NC* price strategies for the remaining periods. The game is solved by backward induction.

**Full Commitment algorithm**

The *FC* algorithm computes the equilibrium as a two stage game between the publisher and the consumers. In the first stage, the publisher announces the prices and, by credible commitment, sets the consumers price expectations. In the second stage, demand is realized along the announced price path.