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Do Consumers Correctly Expect Price Reductions? Testing Dynamic Behavior

Abstract

The literature on both theoretical and empirical dynamics requires agents to solve complex dynamic programs, which assumes implicitly that agents are fully rational and have the most accurate expectations given their information set. We claim that this assumption is easily testable provided that market-level data on prices and purchases are available. Using data on albums exhibiting frequent episodes of promotions, we perform a test derived from the predictions of a simple demand model and find that consumers hold simple expectations on the timing of promotions: everything happens as if consumers were expecting a Markov price process. Our results are consistent with the idea that the rationality of consumers is bounded because of limited memory or limited capacity. These results have important implications in terms of demand estimation, firms' optimal pricing strategy and computation of the welfare.

Keywords: Testing expectations, dynamic behavior, sales, imperfect information, bounded rationality

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Les consommateurs anticipent-ils correctement les promotions ? Un test de comportement dynamique

Résumé

Dans la littérature à la fois empirique et théorique, les agents économiques résolvent des programmes dynamiques complexes, étant donné leur ensemble d'information, ce qui suppose implicitement que les agents sont entièrement rationnels et forment les anticipations appropriées. Nous mettons en avant l'idée que cette hypothèse est testable sur données détaillées au niveau d'un marché, comportant prix et volumes des ventes. A l'aide de données sur des œuvres musicales exhibant de fréquents épisodes avec des promotions, nous testons les prédictions d'un modèle de demande et trouvons que les consommateurs forment des anticipations simples au sujet du processus de prix : tout se passe comme si les consommateurs s'attendaient à un processus de prix de type Markov d'ordre 1. Ces résultats sont cohérents avec l'idée d'une rationalité limitée des agents, en raison d'une mémoire ou d'une capacité limitée. Ils ont des conséquences importantes en termes d'estimation de la demande, de la stratégie optimale de prix et de mesure du bien-être sur un marché.

Mots-clés : Test des anticipations, comportement dynamique, promotions, information imparfaite, rationalité limitée

Classification JEL : D11, D12, D22, D84

1 Introduction

The importance of taking agents' dynamic behavior into account has been well emphasized by the theoretical literature on industrial organization. It is for instance often assumed that consumers anticipate future prices and behave strategically. For instance, Stokey (1981) requires consumers to be perfectly forward-looking in order to construct the unique perfect equilibrium that leads to the Coasian outcome. Similarly, a growing empirical literature on industrial organization has investigated the estimation of games in which agents are fully rational and dynamic: seminal contributions include Aguirregabiria and Mira (2007), Bajari et al. (2007), Pesendorfer and Schmidt-Dengler (2008). Nair (2007) and Esteban and Shum (2007) also derive an intertemporal demand model from an exact dynamic optimization program based on the assumption that agents are perfectly forward-looking.

Though many of these papers make the assumption of full rationality, this is rather demanding in a dynamic setting since it requires agents to hold correct expectations over the future. Other papers estimating structural models of demand like Hendel and Nevo (2006) and Gowrisankaran and Rysman (2011) assume that consumers are fully rational but that the firm fixes prices according to some Markov process. Note that this estimated demand is similar to the one estimated under a different assumption, namely that the firm fixes prices optimally but that consumers expect a Markov process. However, the derivation of optimal prices and the computation of the welfare would be different, since a game in which both the firm and consumers behave optimally differs from a game in which a fully rational firm faces non fully rational consumers; equilibrium prices as well as purchases and profits are not the same. In a recent paper, Hendel and Nevo (2011) posit several hypotheses about consumers' expectations, perfect foresight as opposed to rational expectations, and estimate a model of demand under different assumptions. They find that consumers are heterogeneous in their ability to store and in their price-sensitivity.

This paper argues that the nature of consumers' expectations is testable and proposes a simple method to determine whether consumers hold correct beliefs or not for a specific good. To this purpose, we exploit price variations to infer the nature of consumers' behavior since accumulation, perfect foresight, myopic behavior or expectations based on time-independent information sets shall correspond to distinct patterns of demand.

First, we claim that the availability of market-level data of prices and purchases is sufficient to perform the test before the estimation of any structural model. To understand how consumers form their expectations about the price process, we need to observe how the demand reacts to some price change. We recognize that markets with highly volatile prices are not suited to such an analysis since it would be hard to disentangle the price effect from what is due to expectations. However, markets with sticky prices with occasional price changes (for instance, promotions) are appropriate to perform such a test. Intuitively, the pattern of demand should decrease when a price reduction approaches if consumers hold correct expectations, while it should stay flat otherwise. Facing firms that cut prices occasionally, consumers with correct expectations should anticipate that a sale is more and more likely to occur as time goes by and the price remains high. This prediction is quite strong since it holds as soon as at least some fraction of the population has some information at her disposal and is able to use it for making her decision.

Second, we perform the test using data on albums that exhibit occasional price reductions (sales or durable price changes) and find, though non-surprisingly, that consumers do not have correct expectations about prices in this market. However, consumers do take dynamic decisions since they cumulate and do wait for a lower price, but make mistakes about the schedule of price reductions. We find that the pattern of purchases is essentially flat before a price reduction while the price stays constantly high, which indicates that consumers are rather naive. Besides, the myopic hypothesis is ruled out: we find evidence that consumers postpone their decision of purchase and wait for a lower price. We conclude that consumers are aware of promotions and wait for them, but have seemingly a wrong timing in mind or form "simple" expectations, that they do not update accordingly as time goes by. They behave as if the firm was setting prices as a function of lagged prices only. On the contrary, the firm looks strategic enough and does not set prices according to this simple process: the timing of promotions is found to depend on the duration since the last one. In this market, it would be more appropriate to assume that the firm is rather fully rational with perfect foresight while consumers have simpler expectations.

These aspects are important and play a key role, especially when dynamic decisions are involved. The rationality assumption is quite demanding in such settings: consumers are required not only to optimize but also to form correct expectations over future sequences of prices given their past information. In particular, not only preferences matter but also *perceived opportunities* (Vriend (1996)) that include all relevant information for the consumer's choice. The rational expectations hypothesis (Muth (1961), Lucas (1995)) states that agents collect relevant information and anticipate correctly the whole price path. An exhaustive empirical literature aims at testing this assumption; results depend on economic issues that are considered. Much attention has been devoted to price processes, which is especially relevant for macroeconomics to assess whether perceived inflation coincides or not with the actual rate. Famous examples of tests include Lucas (1972), Sargent et al. (1973) and Barro (1977).

The psychological literature tends to argue that consumers expectations may not be perfect because of intrinsic limitations. Turnovsky (1970) and Lovell (1986) bring empirical evidence that casts doubts on the validity of the rational expectations hypothesis. According to Manski (2004), the coincidence between subjective beliefs and objective probabilities is an extreme assumption that is not likely to hold for most agents. Clerides and Courty (2010) bring also evidence of consumer inattention by looking at sales.

However, concerning income distributions, Dominitz and Manski (1997) find that subjective perceptions are close to actual distributions. Looking at life expectancy, Hamermesh (1985) as well as Hurd and McGarry (2002) show that individual beliefs are consistent with the rational expectations hypothesis: older people have higher subjective life expectancies and people take the past into account in forming their expectations.

The paper is organized as follows. In the next section, we expose a simple model that explains how expectations can be recovered from the observation of demand. Section 3 presents the data we use. Section 4 documents the strategy used by the firm and especially the fact that sales are predictable. Section 5 is devoted to the test of consumers expectations and Section 6 discusses our results with respect to the firm's strategic and dynamic behavior. Section 7 concludes.

2 Dynamic demand and consumer expectations

In this section, we explain what can be learned from the demand observation of a durable good about consumer expectations when a firm uses sticky prices with a regular price and occasional sales at a lower price. To capture all the intuitions, we consider a discrete time setting and suppose that the firm charges a high price $\bar{p}$ during n periods and cuts prices at $n+1$ to $\underline{p} < \bar{p}$. The sale lasts several periods, say s, and such cycles repeat over time. We will show that this simple framework enables us to discriminate between different kind of information used by consumers to form their expectations.

More precisely, we suppose that the demand comes from impatient consumers who discount the future at factor $\delta \in [0; 1]$. These consumers are heterogeneous among their valuation $v \in [0; +\infty[$ distributed according to some cdf $F(.)$. Their current utility at t writes $v - p_t$. Every period new identical cohorts of consumers arrive in the market with a mass normalized at one whereas old cohorts of consumers remain in the market until the next period with probability $\alpha \in [0; 1]$. The timing is thus the following: at the beginning of period t, a new cohort arrives and joins consumers who remain in the market, all consumers observe prices and the demand is formed. People who do not purchase either drop out or remain in the market until period $t + 1$.

Dynamics is at stake only if some consumers remain in the market i.e $\alpha > 0$. Indeed, when $\alpha = 0$, we face a repeated static game. Regardless of their expectations, buyers in period t are new consumers whose valuation is higher than the current price. The

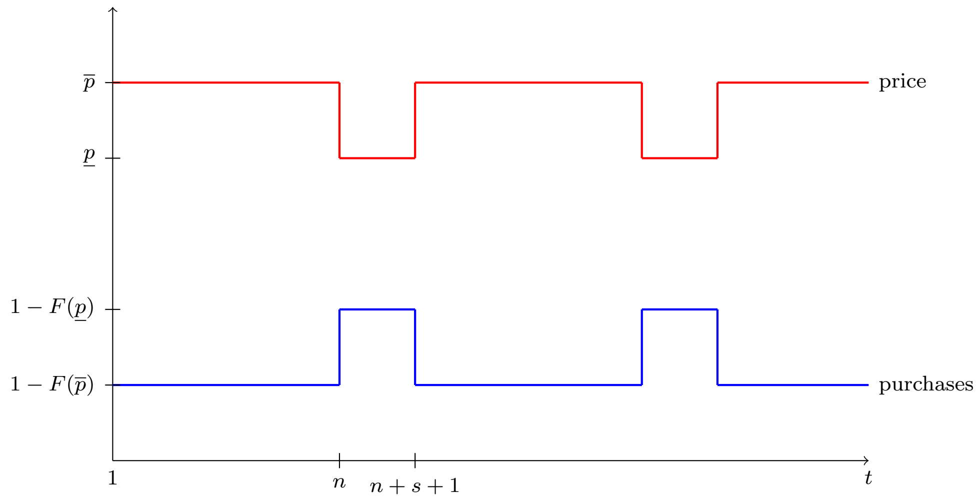


Figure 1: No accumulation

demand is equal to $1 - F(\bar{p})$ when the price is high and to $1 - F(\underline{p})$ when the price is low. This yields to flat patterns of purchases as described by Figure 1. On the contrary, when $\alpha > 0$, the pattern of purchases depends on consumers' expectations about prices and sales.

2.1 Perfect foresight or imperfect and time dependent information

We first suppose that consumers have perfect foresight regarding prices. This means that they perfectly anticipate that the firm uses price cycles and perfectly know where they are in that cycle. In period $t = 1, ..., n$, a consumer with valuation v buys if and only if

$$v - \bar{p} \geq (\alpha\delta)^{n-t+1}(v - \underline{p}) \tag{1}$$

that is

$$v \geq v_n(t) \equiv \frac{\bar{p} - (\alpha\delta)^{n-t+1}\underline{p}}{1 - (\alpha\delta)^{n-t+1}} = \bar{p} + \frac{(\alpha\delta)^{n-t+1}}{1 - (\alpha\delta)^{n-t+1}}(\bar{p} - \underline{p})$$

Because $v_n(t)$ is increasing with time t, the demand, given by $1 - F(v_n(t))$, decreases with t. This result is quite intuitive: as time goes by, the date of the sale is approaching and more and more consumers wait for the sale. This effect induces a declining pattern of purchases over time when the price is high. This declining pattern is the dual of the declining pattern of prices described in Conlisk et al. (1984). They show that a firm facing consumers with discrete heterogenous valuations uses price cycles in which the price decreases. The firm wants high valuation consumers to purchase as soon as they enter the market and prices decrease to make them indifferent between purchasing immediately or later on. The firm thus lower prices when a sale approaches and quantities are constant over time. Our point of view is exactly dual. Fixing the firm's strategy at a constant price during n periods, purchases are decreasing to reflect that consumers are more likely to wait for the sale.

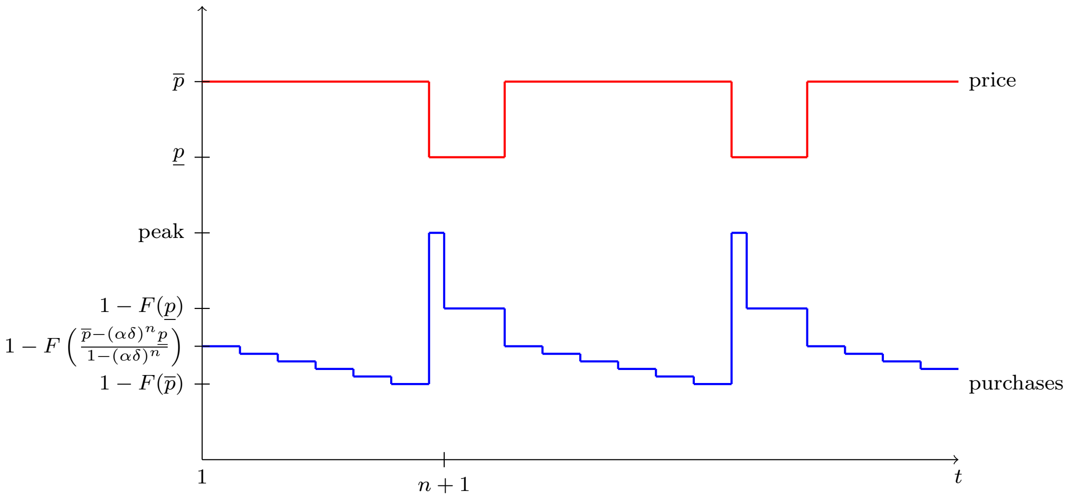


Figure 2: Accumulation and time dependent information

More generally, this analysis indicates that the declining pattern should be observed not only if consumers perfectly foresight prices but also as soon as at least some consumers know that, as time t goes by, the sale is closer and/or more likely to happen. Indeed, even with imperfect information, a declining pattern will arise as soon as consumers at time $t+1$ are aware, given their information set, that they have a greater incentive to wait than consumers at time t. We will say in that case that consumers face imperfect but time dependent information about the sales. Note finally that $v_n(t)$ and thus the current demand q_t during high prices do not depend on n but on the remaining time $n - t + 1$ until the next sale.

We now turn to the pattern of purchases during sales. At the beginning of the sale, in period $n+1$, consumers of all cohorts are present in the market. Indeed, at the end of each period t, consumers whose valuations were lower than $v_n(t)$ but greater than $\underline{p}$ decided to wait for a sale. As they remain in the market until period $n+1$ with probability α^{n-t+1}, there is a peak of demand at the beginning of the sale equal to

$$\sum_{t=1}^{n} \alpha^{n-t+1}[F(v_n(t)) - F(\underline{p})] + 1 - F(\underline{p}). \tag{2}$$

This peak comes both from accumulation of low-valuation consumers and from strategic behavior implied by perfect expectations. It increases in particular when n increases, because more consumers have accumulated. During the rest of the sale, since the stock of consumers who were waiting for a low price had been emptying out in period $n+1$, the demand is made up only of new consumers. All new consumers with a valuation greater than $\underline{p}$ have an incentive to buy immediately and the demand is thus equal to $1 - F(\underline{p})$.

Figure 2 summarizes the pattern of demand that should be observed if consumers have perfect foresight regarding prices.

2.2 Myopic or uninformed consumers

Let's now turn to the case of myopic consumers who do not value the future: $\delta = 0$. The consumer decision is thus static and the consumer buys the good if and only if his valuation is above $\bar{p}$. Hence, the pattern of purchases is flat and equal to $1-F(\bar{p})$ during a period with a high price. A similar pattern would also be observed with consumers who value the future but do not have any information about the prices used by the firm and thus only take their decision on the current price they observe. In both cases, the demand is flat and only depends on $\bar{p}$.

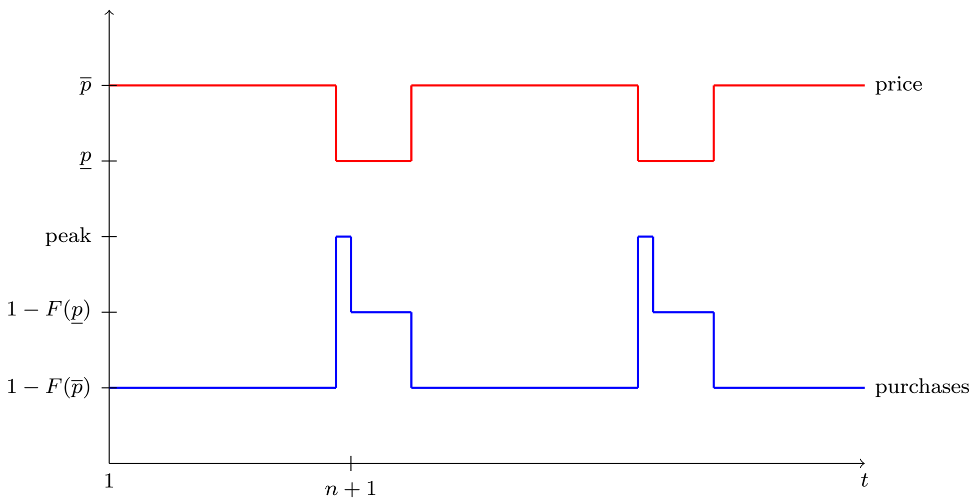


Figure 3: Accumulation and myopia

Then, at the beginning of the sale, because consumers accumulate, we should observe a peak of demand given by

$$[F(\bar{p}) - F(\underline{p})]\alpha \frac{1-\alpha^n}{1-\alpha} + 1 - F(\underline{p}). \tag{3}$$

However, contrary to the previous case, the peak comes only from accumulation of low-valuation consumers but not from strategic delaying of purchases. Finally, once the stock of consumers is emptied out, the demand during the rest of the sale is flat and given by $1 - F(\underline{p})$. The whole pattern is depicted in Figure 3.

2.3 Imperfect and time independent information

Finally, we study an intermediate situation in which consumers have some information about the prices and sales used by the firm but do not take into account that, as time t goes by, the sale is closer and/or more likely to happen. We say that consumers face imperfect and time independent information about the sales. This would be the case for instance if consumers do not know whether the last sale happened one week or one month ago even though they know that a sale occurs every quarter. As a result, they will assign some constant probability $\frac{1}{n}$ over time to each period $t = 1, ..., n$.

Their decision to purchase at time t will thus be based on the intertemporal trade-off with respect to the n future periods and consumers will buy the product if and only if:

$$v - \bar{p} \geq \sum_{\tau=t+1}^{t+n} \frac{1}{n}[(\alpha\delta)^{\tau-t}(v - \underline{p})] = \sum_{\tau'=1}^{n} (\alpha\delta)^{\tau'} \frac{v - \underline{p}}{n} \tag{4}$$

that is

$$v \geq w_n = \bar{p} + \frac{\frac{\alpha\delta}{n}\frac{1-(\alpha\delta)^n}{1-\alpha\delta}}{1 - \frac{\alpha\delta}{n}\frac{1-(\alpha\delta)^n}{1-\alpha\delta}}(\bar{p} - \underline{p}) \tag{5}$$

The corresponding pattern of purchases during periods with a high price is flat and the demand is $1 - F(w_n)$ where w_n decreases with n. The peak at the beginning of the sale is equal to

$$[F(w_n) - F(\underline{p})]\alpha\frac{1 - \alpha^n}{1 - \alpha} + 1 - F(\underline{p})$$

whereas the demand during the rest of the sale is, as usual $1 - F(\underline{p})$.

A similar result is obtained if we suppose that consumers act as if there was a probability $\lambda = \frac{1}{n}$ that the album is on-sale at each period. Indeed, in that case, consumers would buy at t if:

$$v - \bar{p} \geq (\alpha\delta)\left[\left(1 - \frac{1}{n}\right)(v - \bar{p}) + \frac{1}{n}(v - \underline{p})\right]$$

that is

$$v \geq w'_n = \bar{p} + \frac{\alpha\delta}{1 - \alpha\delta}\frac{1}{n}(\bar{p} - \underline{p}) \tag{6}$$

which leads to the same pattern than previously, as depicted in Figure 4.

Because the consumer information is time independent, w_n and w'_n do not depend on t and we do not observe a declining pattern as in Figure 2. On the contrary, Figures 3 and 4 look qualitatively very similar with a flat demand when prices are high. Yet, the levels of the demand are very different. On one hand, myopic or uninformed consumers only take their decision on $\bar{p}$. On the other hand, w_n and w'_n do not only depend on $\bar{p}$ but

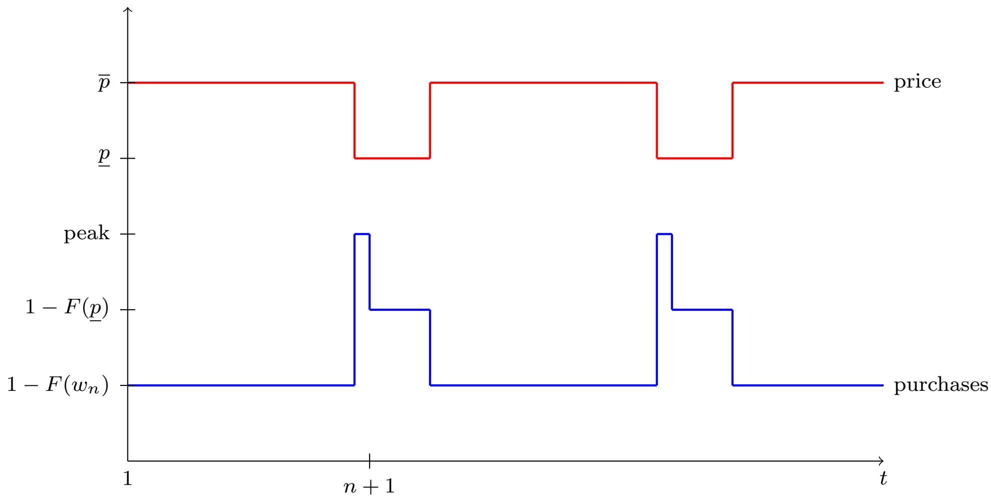


Figure 4: Accumulation and time independent information

also vary with $\underline{p}$ and n. The more attractive the sale appears, the smaller the demand is outside sale periods. The demand during high prices increases with the price during sales because the sale is less profitable. Similarly, when n increases, the demand during high prices increases because a sale is less likely to occur. The characteristics of the sale influence the demand level but not the pattern of purchases when prices are high.

2.4 Predictions

Using the predictions of this basic model, we can first test if dynamics plays an important role in the market. To do so, we have to study the accumulation process.

Prediction 1 *Dynamics is relevant and important if*

- *The demand is higher at the beginning of the sale than at the end of it*
- *The demand at the beginning of the sale increases with $\bar{p}$, the price used off the sales*
- *The demand at the beginning of the sale increases with n, the time since the last sale*

If dynamics is important, our simple model also provides conditions to test the nature of information used by consumers to form their expectations and take their decisions.

Prediction 2 *If consumers either perfectly foresight the prices or use imperfect but time dependent information about the sales to form their expectations and take their decisions, the purchases should*

- *decrease during periods when the price stays constantly high*
- *be greater after a sale than before it*
- *decrease with $\bar{p}$, the price used off the sales*
- *increase with $\underline{p}$ the price during the sale*
- *not depend on n, the time since the last sale*

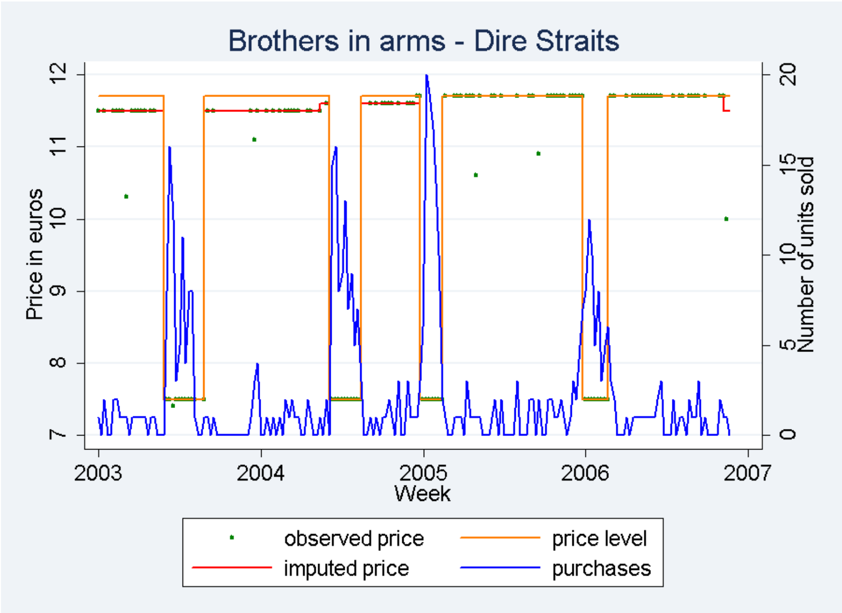
Prediction 3 *If consumers are either myopic or do not use any information about the sales to form their expectations and take their decisions, the demand during periods when the price stays constantly high should stay constant and not depend on anything but the current price.*

Prediction 4 *If consumers use imperfect and time independent information about the sales to form their expectations and take their decisions, the demand during periods when the price stays constantly high should*

- *stay constant*
- *be similar after a sale and before it*
- *decrease with $\bar{p}$, the price used off the sales*
- *increase with $\underline{p}$ the price during the sale*
- *increase with n, the time since the last sale*

3 Data

In France, the music industry is heavily concentrated: non-specialized superstores have an aggregated market share of 40%, as specialized superstores do, the rest of the sales being made by independents or other retailers. We have data from the most important French music retailer, selling 25% of albums and thus the main specialized chain with 62.5% of the market. Our working sample is made up of 121 records that are sold the most in its 10 major stores from January 2003 to November 2006. Six stores are located in Paris while the four remaining stores are in large French cities: Grenoble, Lille, Lyon and Toulouse. Our balanced panel has $245,630$ observations; each observation corresponds to some record j that was sold (or not) by store r in week t going from 1 to 203. For each observation some characteristics X_j of the disc are available, including its author, its title and the name of its *major* (Sony, Warner, EMI...). We know how many albums were sold, *i.e.* the quantity q_{jrt}, and how much revenues R_{jrt} these sales generated: prices are



(a)

(b)

Figure 5: Typical price and quantity patterns

then computed from the ratio $\frac{R_{jrt}}{q_{jrt}}$. In the case where a disc was not sold however, *i.e.* when $q_{jrt} = 0$, the price is missing.

These albums come from the "world- and pop- music department" and were all released before 2001. This selection rules out new albums whose price strategies are specific to the introduction of a new good. As albums do not depreciate over time, and because consumers generally purchase an album at most once, these products are thought to be typical durable goods. Titles of most famous albums in our sample include for instance Nevermind (Nirvana), Platinum Collection (Queen), Doors (Doors), Led Zeppelin IV (Led Zeppelin), Parachutes (Coldplay), One (The Beatles), Andy Warhol (Velvet Underground), Wall (Pink Floyd). Appendix A provides the full list of albums.

An important issue comes from observations with no purchase: they account for 48% of the sample. In that case, when a price is missing, we follow a standard procedure to recover actual prices. Our method follows closely the one described by the Kilts Center for Marketing (Chicago Booth GSB) that provides publicly databases including data on ketchup like the one used by Pesendorfer (2002). The complete procedure is described in Appendix B.

These data provide information about the evolution of purchases and prices over time for every album-store. Price patterns look similar to those exhibited by Pesendorfer (2002) on ketchup brands: long periods of high prices with occasional price cut followed by a return to the previous price. Figure 5 displays typical joint patterns of prices and purchases. Specifically, there are two types of price changes: sales and durable price cuts, which we will first define and then describe.

3.1 Price reductions: sales and durable price changes

On the one hand, sales are occasional and may last from 3 to 8 weeks, with a discount that is on average about 30%. On the other hand, durable price changes correspond to the firm's fixing a new lower regular price. From Figure 5 for instance, we see that the price of the album "Greatest hits" by Janis Joplin falls frequently from 11.5 to 7.5 euros on sale but from August 2005, the regular price switches from 11.5 to 10.6 euros, while sales at 7.5 euros still occur. In that case, we have what we call a "durable price change". Such changes shall not be disregarded in our analysis. According to Prediction 1, if consumers do not cumulate, a flat pattern must be observed after the price falls, while some (small) peak of demand should be observed otherwise. Furthermore, if consumers have correct expectations, they should anticipate this price fall.

We may observe several consecutive price reductions. In that case, we want to test for the anticipation behavior over the period that precedes the first price reduction, but for accumulation over every period with a lower price than the price before the first price reduction, controlling for the fact that the price keeps on falling. Put differently, if consumers do cumulate, a peak of demand should be observed every time the price decreases.

Finally, we have also small price reductions that are temporary discounts – observed during 1 or 2 weeks – for regular shoppers and that correspond to the firm's customer-oriented price policy. We observe 2,314 reductions of this type, for which the median discount is 9.3%. Thus, they are distinct from our object of interest, involving more substantial and durable price cuts.

For this bunch of reasons, we define any downward change in a "price level" as a "price reduction". Price levels correspond to most frequent prices, taking inflation into account as Figure 5 shows. They are defined at the album-store level. We obtain for each album-store between 1 and 10 price levels during the whole period of observation, most of them having about six price levels.

Table 1: Prices

	Price level		Number of prices	
	I	II	III	IV
	Frequency	Cumulated	Frequency	Cumulated
1	61.54	61.54	0.83	0.83
2	18.67	80.20	9.09	9.92
3	8.94	89.15	22.56	32.48
4	5.45	94.59	30.99	63.47
5	3.45	98.04	20.66	84.13
6	1.46	99.50	10.50	94.63
7 to 10	0.50	100.00	5.37	100.00

Table 1 actually shows that 95% of the time, one of the four highest prices is charged, which indicates that prices are very sticky. To anticipate, this piece of evidence claims in favor of price exogeneity since prices are not likely to be correlated to current idiosyncratic shocks: otherwise, the distribution of price levels would look much more uniform than the one displayed by Table 1, Column II.

To sum up, we will test consumers' behavior on these "price reductions" corresponding either to a sale or a durable price change. Weeks before such price reductions shall be used to test the anticipation part, while weeks during those episodes shall be used for the accumulation part. Importantly, we focus on sequences of high prices followed by (multiple) price reductions. Such sequences are defined by their end, *i.e.* by the moment when the price decreases.

Table 2: Durations of "high-price/low-price" sequences

	mean	std	min	max	med
High price	30.1	27.3	3	169	21
Low price	10.0	11.4	3	115	7
Whole sequence	40.1	31.6	6	202	30

$N = 2,833$ *sequences of high-price/low-price.*
Durations are computed in weeks.

Note that it is essential to consider sequences that begin with a price equal to the *highest price level* in order to test for anticipation. Otherwise, any medium price level can be seen as a price reduction from the highest price level and a decreasing pattern coming from accumulation of consumers whose valuation lies between this price and the highest price level: in other words, such periods could mix both anticipation and accumulation. As a result, to keep the test as pure as possible, we restrict our attention to $2,833$ sequences that are strictly speaking a "high-price/low-price": if several consecutive price reductions occur after a period with the highest price level, we consider only the first one to avoid the previous problem. Finally, we must focus on such sequences that are fully observed, excluding those for which we don't know exactly the beginning, in which case we ignore the duration of the "high-price" period (see Table 2). On those interior sequences, one can see that they typically last 40 weeks: 30 weeks with the highest price and 10 weeks with a smaller price, though there is some heterogeneity in these durations.

3.2 Prices during price reductions

Characteristics of sales can be found in Table 3. The average price on (resp. off) sale is 9.9 (resp. 16.2) euros, which yields a discount of about 40%. The typical sale lasts 5 weeks, which is the mode of durations, and every album-store is on sale about once a year. As Figure 5 shows, there is no clear seasonality in the timing of such promotions. On average, every week in every store, about 7.5% of albums are on-sale.

Characteristics of durable price changes can be found in Table 4. Contrary to sales, durable price changes last longer: about 22 weeks. They involve a discount that is somehow close to 35%. Furthermore, almost every album knows at least one durable price change, which indicates a tougher price competition, mainly related with the growing competition with Internet and the development of the peer-to-peer device.

Table 3: Sales

	mean	std	min	max	med
Price (non-sale, in euros)	16.2	5.7	4.2	41.6	16.7
Price (on-sale, in euros)	9.9	4.9	2.5	36.7	7.5
Number of sales (per album-store)	4.0	2.3	0	11	4
Duration (weeks)	7.4	4.3	3	60	6
Time spent on sale (fraction, %)	14.6	9.3	0	49.3	13.8
Discount (%)	37.8	15.9	5.1	79.5	37.4
Revenues (fraction, %)	35.0	20.5	0	82.5	34.9

$N = 4,831$ *sales*

Table 4: Durable price changes

	mean	std	min	max	med
Price (euros)	11.4	4.7	5.0	36.7	10.6
Number of durable price changes (per album-store)	0.9	0.6	0	2	1
Duration (weeks)	21.9	22.2	3	115	13
Discount (%)	35.3	20.0	5.4	73.1	35.4

$N = 1,109$ *durable price changes*

3.3 Purchases

Turning now to purchases, the number of albums sold varies from 0 to – coincidentally – 203 per week, store and album. From Table 5, the average quantity on (resp. off) sale is 7.14 (resp. 1.05). These figures are consistent with the literature devoted to sales: in this market, the demand is about 6.8 times higher during a promotion.

Going back to Figure 5, we observe a clear peak of purchases at the beginning of sales followed by a strongly decreasing pattern of demand, which claims in favor of accumulation. We will document this phenomenon more formally in the next section but we note already on Table 5 that the average quantity sold during a sale[1] is 7.14 per week while it is 9.87 during the second week and still 8.68 on the third week. There seems to be a peak of demand at the beginning of sales which is about 9.4 times the usual demand, 1.05 album per week and per store. After the peak, purchases decrease until an

[1]here are the statistics for sales only. The same could be done for durable price changes. More striking figures are obtained on sales.

Table 5: Weekly purchases

	mean	std	min	max	med
Quantity (non-sale)	1.05	2.30	0	91	0
One month after a sale	1.31	2.34	0	33	1
Two months after a sale	1.17	2.07	0	37	0
One month before a sale	1.11	2.93	0	72	0
Two months before a sale	1.04	2.37	0	72	0
Quantity (on-sale)	7.14	10.73	0	203	3
First week of sale	7.12	9.39	1	86	4
Second week of sale	9.87	13.10	1	146	5
Third week of sale	8.68	12.11	0	128	4
Tenth week of sale	4.07	7.94	0	107	2

Computations from 4,831 *sales*

average of 4.0 after 10 weeks[1], which seems to rule out a flat pattern of purchases during a sale and suggests thus that consumers do cumulate. Since we aggregated daily data at a weekly level, the first week at the beginning of a sale necessarily mixes few days with a high price and the rest of the week with a low price, which explains that the average quantity sold during such a week is smaller than on the second week, consistently with the results of the next section.

Another argument in favor of accumulation is provided by Table 6. First, comparing columns of Table 6 suggests the existence of a decreasing pattern of purchases during price reductions, since the average level of purchases is higher at the beginning than at the end of price reductions. Second, comparing now rows, the longer the duration of the period with a high price before a price reduction – n in the model of section 2 –, the higher the peak of demand at the beginning of the price reduction: the difference previously mentioned increases from 1.32 when n is small to 2.76 when n is large. When n is small, about 8 albums are sold at the beginning of sales, while 14 albums are sold when n is higher: this large and significant difference seems to account for accumulation. However, these descriptive statistics do not control for the discount effect: for a given n, the peak of demand is higher if the price on sale is lower. Such effects, as well as time effects, have to be controlled for, and that is the reason why we proceed to the econometric test in the next section.

In the same vein, and still having a careful look at Table 5, we do not see any strong decreasing pattern of the demand during weeks when the price is high. Indeed, the

[1] if any, since sales generally last less than 10 weeks

Table 6: Weekly purchases during price reductions

	average nb of purchases			diff
	first two weeks	first month	whole price reduction	I-III
	I	II	III	IV
$n < 10$ weeks	7.83	7.74	6.51	1.32
	(0.51)	(0.52)	(0.41)	(0.65)
$10 \leq n < 20$ weeks	7.94	7.97	6.64	1.30
	(0.37)	(0.40)	(0.34)	(0.50)
$20 \leq n < 30$ weeks	10.37	9.91	8.05	2.32
	(0.56)	(0.54)	(0.43)	(0.71)
$30 \leq n < 40$ weeks	14.25	14.17	11.49	2.76
	(0.68)	(0.66)	(0.53)	(0.86)

Note: n is the elapsed time between previous and current price reduction

average quantity is 1.11 during such periods while it is 1.31 (resp. 1.17) one month (resp. two months) after a sale and 1.11 one month before (resp. 1.04 two months before), with small and erratic variations week after week; these differences are not significant at the usual 5% level and claim in favor of a flat pattern during periods with high prices.

3.4 Heterogeneity

An analysis of variance indicates that an important part of the price dispersion comes from the heterogeneity across albums. We run the following regression:

$$p_{jrt} = \delta_j + \delta_r + \delta_t + \epsilon_{jrt}.$$

We find on Table 7 that the album part δ_j explains 75.3% of the total variance while the time effect δ_t has only a marginal impact, 1.9%. The variance explained by store effects δ_r is less than .04%, which confirms that the price policy is fixed at a national level.

Table 7: Analysis of variance

	prices	purchases
Time effects	0.019	0.038
Album effects	0.753	0.103
Store effects	0.0004	0.019

$N = 245,630$ *observations*

The same decomposition of variance is done for purchases as well:

$$q_{jrt} = \delta_j + \delta_r + \delta_t + \epsilon_{jrt}.$$

It leads us to conclude that album, store and weekly effects explain a small though significant part of the variance in purchases. Product effects account for 10.3% of the heterogeneity in purchases only, stores explain 1.9% of the variance and time effects matter for 3.8%.

This analysis of variance enables us to conclude that heterogeneity matters in this framework and motivates the necessity of controlling for observed effects like time, album-store and price effects, which is done in the next section.

4 The firm

Contrary to consumers, firms do spend money and time to analyze consumers behavior in their marketing departments, to gather and record relevant data. For this reason it is much more likely that they behave optimally. We argue here that even though consumers may have naive expectations about the price process, the firm does not set prices naively. Its behavior turns out to be close to what an optimal firm would do.

First, from Figure 5 one can see that prices are sticky which contradicts the idea that the firm plays a static and repeated strategy. To check it formally, we regress current prices p_t on past prices. Results are found in Table 8. We introduce one lag. Column I shows that the coefficient β_{t-1} of p_{t-1} is close to 1 and strongly significant as expected. Prices are serially correlated over time and not independent like in the prediction of Varian (1980). The rejection of $H_0 : \beta_{t-1} = 0$ leads indeed to reject the static repeated game in our framework and to accept the idea that on the contrary, the firm behaves dynamically.

Second, adding more lags of the price as covariates, we find that the firm takes previous past prices into account when fixing prices, and not only the last one. Column II and III from Table 8 show that p_t depends on $p_{t-2}, p_{t-3}, p_{t-4}, p_{t-5}$. We test H_0 : $\beta_{t-2} = \beta_{t-3} = \beta_{t-4} = \beta_{t-5} = 0$. The $F-$stat is 582.3 and leads to a clear rejection of H_0 at the 5% level. Columns IV to VI do the same exercise with observations that do not come from imputation; they lead to the same conclusions. As a result, the firm does not fix prices according to the (first-) lagged price only.

Third, following the empirical analysis led by Pesendorfer (2002) on sales, we estimate the impact of the duration since the last price reduction on the probability of having a price reduction. We define S_{jrt} as a covariate equal to 0 when the price is high and to 1

Table 8: Dynamics of prices

	Price p_t					
	I	II	III	IV	V	VI
p_{t-1}	0.889*** (0.001)	0.931*** (0.002)	0.926*** (0.002)	0.887*** (0.002)	0.907*** (0.005)	0.867*** (0.006)
p_{t-2}	.	0.001 (0.003)	0.001 (0.003)	.	0.018*** (0.006)	0.032*** (0.008)
p_{t-3}	.	−0.058*** (0.002)	−0.007*** (0.003)	.	−0.064*** (0.004)	0.013*** (0.008)
p_{t-4}	.	.	−0.030*** (0.003)	.	.	−0.040*** (0.007)
p_{t-5}	.	.	−0.026*** (0.003)	.	.	−0.048*** (0.005)
Album-store effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.95	0.95	0.95	0.95	0.95	0.94
Number of observations	243,814	241,400	238,986	85,021	50,787	34,817

during the first period of a price reduction. We specify a simple Logit model:

$$S_{jrt} = \mathbb{1}[\gamma_a \, \text{duration} + \delta \, t + \xi_{jr} + \epsilon_{jrt} > 0],$$

results of which are shown in Table 9. We reject $H_0 : \gamma_a = 0$ against $H_a : \gamma_a > 0$ at the 5% level, which indicates that the probability of a price reduction is an increasing function of the duration since last price reduction. To check whether this relationship is stable, we allow γ_a to vary over time (Column II): though the coefficient falls after 2004, the relationship is still increasing. Put differently, a price reduction is more likely to occur as time goes by.

In the same vein, we find that the length of a price reduction increases with the duration since the last price reduction, which is a best response of the firm to the accumulation of consumers. Indeed, while theoretically the peak of demand occurs during the first week of a price reduction, we have already observed that it takes several weeks to empty out the stock of consumers. As a result, the larger the interval between sales is, the more consumers cumulate and it takes longer to empty this stock out. We find evidence of such a correlation on Table 9.

To sum up, the firm fixes prices according to a rather complex and dynamic strategy. She does not play any repeated static game like in Varian (1980). Current prices depend not only on the past price but also on previous past prices. Moreover, the probability of a price reduction increases with the duration since the last promotion, which is consistent with a dynamic optimal behavior facing a cumulating demand. The firm takes the

Table 9: Fixation of price reductions

Price reductions	Probability		Length
Model	Logit		OLS
Duration since last sale	0.046*** (0.001)	.	.
Duration since last sale×2003	.	0.069*** (0.004)	.
Duration since last sale×2004	.	0.045*** (0.002)	.
Duration since last sale×2005	.	0.045*** (0.002)	.
Duration since last sale×2006	.	0.050*** (0.002)	.
n	.	.	0.021** (0.009)
Album-store effects	Yes	Yes	Yes
Time trend	Yes	Yes	Yes
R^2	.	.	0.68
log L	-9,897	-9,870	.
Number of observations	88,192	88,192	2,833

past into account in her pricing strategy and behaves as if she were fully rational and intertemporal. However, this assumption should be properly tested with a structural model, comparing with what an optimal firm would do facing the actual demand. An other interesting exercise would consist in estimating a dynamic game between the firm and consumers assuming perfect foresight for all agents, compare profits, surplus and welfare with the actual ones.

5 Testing consumers' behavior

In this section, we provide empirical tests of agents rationality from our market-level data on prices and purchases, by documenting four empirical facts in relation with the four predictions of section 2. From Facts 1 and 2, we find evidence for Prediction 1 stating that dynamics matters. We reject Prediction 2 thanks to Fact 3 and the perfect foresight hypothesis, or at least the fact that consumers take their decisions based on a time dependent information set. Indeed, from a qualitative point of view, our data look like Figures 3 and 4, which means that consumers are either myopic or have a bounded rationality. Fact 4 helps us to reject Prediction 3 and the myopic behavior. We conclude that consumers use a time independent information set and form thus rather naive expectations: Fact 5 turns out to be consistent with Prediction 4.

5.1 Dynamics matters: consumers cumulate

Fact 1 *During a price reduction, the pattern of purchases is decreasing.*

First, we document accumulation by showing evidence for peaks of demand at the beginning of price reductions. We define the covariate *during* as the elapsed time since the beginning of the price reduction: *during* is equal to 1 the first week of the price reduction, 2 the second week, etc. until the end of the price reduction. The covariate *during* is defined only when there is a price reduction. We perform then the simple regression to recover the (trend of the) pattern of purchases during price reductions, controlling for album-store and time effects:

$$q_{jrt} = \beta_d \, during + \beta_x \, X_{jrt} + \xi_{jr} + \delta_t + \epsilon_{jrt}. \tag{7}$$

X_{jrt} includes as controls the number of albums that are on sale in the store at time t, as well as the number of albums by the same author on sale, which both capture the intensity of the substitution effect. Note that the low price $\underline{p}_{jrt}$ could be introduced as a control variable: the usual simultaneity bias in demand equations would not arise here because this price might be correlated with ξ_{jr} but not with the current idiosyncratic shock of demand ϵ_{jrt}. Yet, because of the presence of ξ_{jr}, the identification of the price effect would be rather weak and rely on variations of this price within a given album-store only. Including the price as a covariate does not change our results.

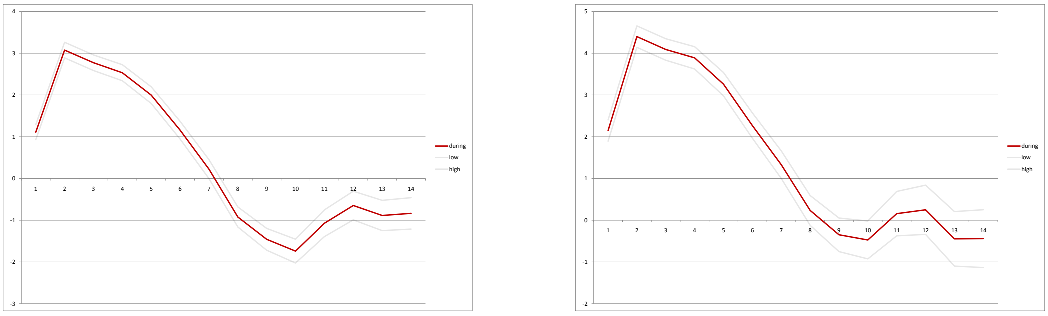
Table 10: Demand during a sale

	Purchases q_{jrt}					
	I	II	III	IV	V	VI
	PR	PR	PR	S	S	S
during	-0.262^{***} (0.014)	-0.253^{***} (0.014)	-0.272^{***} (0.015)	-0.351^{***} (0.022)	-0.355^{***} (0.022)	-0.389^{***} (0.024)
nb albums on sale	.	-0.125^{***} (0.018)	.	.	-0.150^{**} (0.024)	.
nb albums same author	.	1.238^{***} (0.074)	1.149^{***} (0.077)	.	1.841^{***} (0.107)	1.687^{***} (0.113)
Album-store effects	Yes	Yes	No	Yes	Yes	No
Time effects	Yes	Yes	No	Yes	Yes	No
Store-time effects	No	No	Yes	No	No	Yes
Album effects	No	No	Yes	No	No	Yes
R^2	0.59	0.60	0.56	0.60	0.60	0.56
Number of observations	28,382	28,382	28,382	16,727	16,727	16,727

We find on Table 10, Column II, that purchases are strongly decreasing during price reductions: $\beta_d = -0.253$ and is significant at usual levels. In Column III, we replace ξ_{jr} (resp. δ_t) by ξ_{rt} (resp. δ_j), in the case where time and album-store effects would not be the appropriate fixed effects to control for. However, this specification does not explain as much variance (only 56%) as the previous one (60%) and yields close estimates for β_d. We control also for the number of albums on sale within the store: a negative sign (-0.125) accounts for a substitution effect between products, while we find a positive estimate (1.238) for the number of albums on sales by the same author, which accounts for bundle effects. Note that neither the introduction nor the removal (Column I) of such controls does change the result.

Focusing on sales only - as opposed to price reductions - does not change the results either, as shown by Columns IV to VI: the decrease turns out to be even higher with $\beta_d = -0.355$ (Column V).

Finally, discretizing *during*, we plot the average pattern of purchases during a price reduction (resp. a sale).



(a) price reductions (PR)

(b) sales only (S)

Figure 6: Evidence of accumulation

Figure 6 shows that this pattern of demand is highly decreasing and falls continuously after the second week. Indeed, because of the aggregation of daily data, the first week of a price reduction is mixing days when the price was high and some days when it was low. As a result, purchases that week are logically on average lower than the week just after. However, this phenomenon does not occur afterwards and from the second week the decreasing pattern is clear. The magnitude of such an effect is large, which has to be related with Table 6 that pointed out a difference between -1.3 and -2.8 albums per week and per store without any control. From Figure 6 we learn that the effect is still higher by considering the second week rather than the first two weeks for the previous reason: for instance, there are 4 more albums sold in the second week than in the tenth week of a price reduction. Furthermore, the small increase that can be noticed after the 11^{th} week denotes some kind of return to a stationary level, consistently with the model exposed in Section 2. At the end, we notice that even after controlling for album-store and time effects, there is still an almost exponentially decreasing effect that one can interpret as the stock of consumers emptying out, which was already observed in descriptive statistics and that remains large and significant.

Fact 2 *The peak of demand at the beginning of price reductions is higher as n and $\overline{p}$ increase.*

Second, we investigate how this peak varies as n and $\overline{p}$ increase, which is another way of testing whether Prediction 1 holds. From the pattern displayed by Figure 6, we define the peak as the average purchases during the first three weeks of the price reduction, at the exclusion of the first week. n refers to the duration of the period with a high price preceding the price reduction, $\overline{p}$ to the last high price charged and $\underline{p}$ is the current price during the price reduction.

Table 11: Peak at the beginning of price reductions

	Peak of demand
$\underline{p}$	-2.071^{***} (0.086)
$\overline{p}$	2.069^{*} (1.347)
n	0.037^{***} (0.009)
Album-store effects	Yes
Time trend	Yes
Number of observations	2,833
R^2	0.73

Table 11 is consistent with Prediction 1 in the sense that the peak is higher as the duration since last sale increases, which claims again for a peak of accumulation. The impact of the high price $\overline{p}$ is positive though weakly significant. The magnitude of price effects is large, about -2 and $+2$, and the impacts of $\overline{p}$ and $\underline{p}$ tend to be very close to each other. One should not necessarily interpret this equality as evidence in favor of myopic consumers,[1] as will be seen hereafter.

As a result, in our data, the existence of a peak of purchases coming from accumulation of consumers accounts for the importance of dynamics. We accept Prediction 1 and the idea that consumers cumulate.

[1]since from Equation (3), these impacts should nearly coincide if accumulation matters or n is large

5.2 Information is imperfect

Fact 3 *The pattern of purchases is quite flat when the price stays constantly high before a price reduction.*

Third, we test for consumers' anticipation behavior and focus on periods with a high and constant price followed by a price reduction. As already argued, this restriction is motivated by the desire of having a test as pure as possible. Including periods with a constant but intermediate price, i.e. strictly between the highest and the lowest price level, would mix both phenomenons of anticipation and accumulation. At any intermediate price level, there is actually a decreasing pattern that has been put in evidence by Fact 1 and that has nothing to do with the anticipation behavior. Again, the price effect cannot be possibly identified on such periods.

To test our prediction, we define the covariate of interest *before* in such periods as the number of remaining weeks before the price reduction: reasoning backwards from the price reduction, *before* is equal to 1 the first week before a price reduction, 2 the week two weeks before, etc. until the beginning of the period with a high price. To test whether the pattern purchases is decreasing or flat in such periods, we propose to run the following regression:

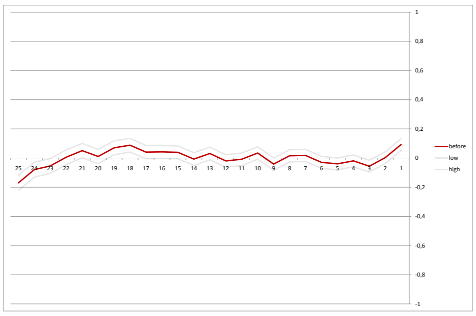
$$q_{jrt} = \beta_b \, before + \beta_x \, X_{jrt} + \xi_{jr} + \delta_t + \epsilon_{jrt}. \tag{8}$$

Table 12: Demand before a sale

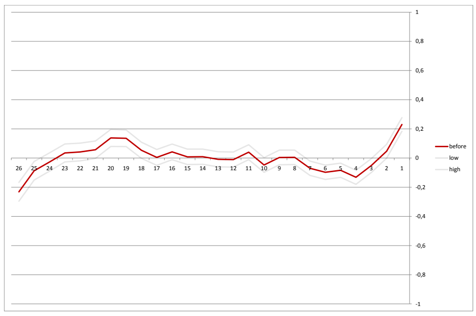
	Purchases q_{jrt}					
	I	II	III	IV	V	VI
	PR	PR	PR	S	S	S
before	$-1.8\,10^{-4}$ $(2.7\,10^{-4})$	$-1.4\,10^{-4}$ $(2.7\,10^{-4})$	$-6.8\,10^{-5}$ $(2.6\,10^{-4})$	0.0024^{***} $(3.9\,10^{-4})$	0.0025^{***} $(3.9\,10^{-4})$	0.0023^{***} $(3.7\,10^{-4})$
nb albums on sale	.	-0.005^{***} (0.002)	.	.	-0.009^{***} (0.002)	.
nb albums same author	.	0.141^{***} (0.010)	0.145^{***} (0.011)	.	0.227^{***} (0.015)	0.231^{***} (0.016)
Album-store effects	Yes	Yes	No	Yes	Yes	No
Time effects	Yes	Yes	No	Yes	Yes	No
Store-time effects	No	No	Yes	No	No	Yes
Album effects	No	No	Yes	No	No	Yes
R^2	0.29	0.29	0.25	0.31	0.31	0.28
Number of observations	85,359	85,359	85,359	60,869	60,869	60,869

Here, the current price $\overline{p}_{jr}$ cannot be introduced as a covariate since its effect is not identified: the regression is performed during sequences of "high-then-low" prices for which the price is always the highest observed at the album-store level. As a result, there is no variation in prices once ξ_{jr} has been controlled for. A decreasing pattern of purchases in these periods must correspond to $\beta_b > 0$ since a higher value of *before* indicates that the price reduction is further away. On the contrary, $\beta_b = 0$ implies that the pattern is flat.

Table 12, Column II, presents the results: we see that $\beta_b = -1.4\,10^{-4}$ is not significant and we can't reject $H_0 : \beta_b = 0$ at the usual 5% level. In other words, there is no decreasing trend in the pattern of purchases when the price is high, and this pattern is quite flat. Contrary to the previous empirical evidence about Fact 1, the effect of *before* is not only insignificant but its magnitude, if any, is small. Restricting on sales only, and thus on more important price changes, yields a positive and significant estimate for β_b (0.0025): this effect is however small in magnitude since it accounts for about 0.25% of sales per week.



(a) price reductions (PR)



(b) sales only (S)

Figure 7: Evidence of imperfect expectations - 1

Again, we discretize *before* to get the whole pattern of purchases in periods with a high price. Results are displayed by Figure 7. The pattern of purchases during those periods is roughly flat. Similarly to what happened previously with the first week during a price reduction, the first week before a price reduction is mixing days with high and low prices: as a result, purchases are on average higher than the weeks before, which leads to a spurious higher level of purchases on this week. Excluding this week, the magnitude of the anticipation effect, if any, would be less than 0.1 in 20 weeks, i.e. 0.005 album per weeks.

Another way to test Prediction 2 is to define the covariate *after* as the elapsed duration since the last price reduction when the price is the highest: reasoning forwards from the

Table 13: Demand after a sale

	Purchases q_{jrt}					
	I	II	III	IV	V	VI
	PR	PR	PR	S	S	S
after	-0.0009^{***}	-0.0007^{***}	-0.001^{***}	-0.0013^{***}	-0.001^{***}	-0.0013^{***}
	($2.6\,10^{-4}$)	($2.6\,10^{-4}$)	($2.6\,10^{-4}$)	($3.8\,10^{-4}$)	($3.8\,10^{-4}$)	($3.7\,10^{-4}$)
nb albums on sale	.	-0.005^{***}	.	.	-0.009^{***}	.
		(0.002)			(0.002)	
nb albums same author	.	0.225^{***}	0.143^{***}	.	0.223^{**}	0.225^{***}
		(0.015)	(0.011)		(0.015)	(0.016)
Album-store effects	Yes	Yes	No	Yes	Yes	No
Time effects	Yes	Yes	No	Yes	Yes	No
Store-time effects	No	No	Yes	No	No	Yes
Album effects	No	No	Yes	No	No	Yes
R^2	0.29	0.29	0.25	0.31	0.31	0.28
Number of observations	85,359	85,359	85,359	60,869	60,869	60,869

beginning of a period with a high price, *after* is equal to 1 the first week of this period, 2 the week after, etc. until the last week of that period, immediately before a price reduction. We regress quantities on this covariate according to:

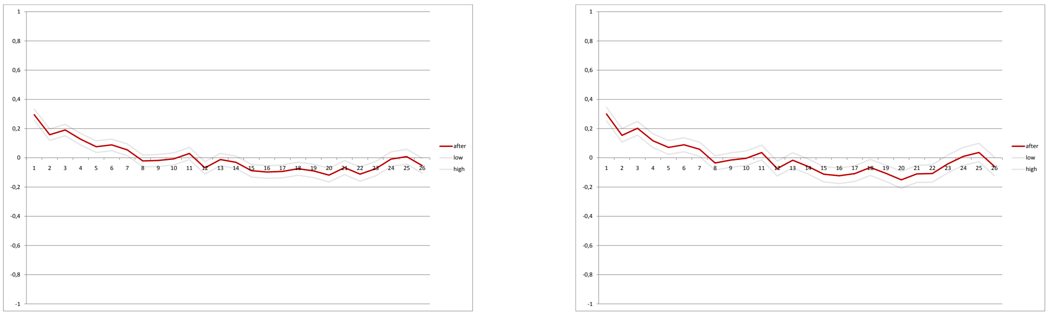
$$q_{jrt} = \beta_a \, after + \beta_x \, X_{jrt} + \xi_{jr} + \delta_t + \epsilon_{jrt} \tag{9}$$

If consumers had perfect foresight or even rational expectations about the price process, $\beta_a < 0$ would indicate that the pattern is decreasing because of strategic delaying of purchases while $\beta_a = 0$ means that the pattern is flat. We find on Table 13, Column II, that the effect is significant at 5% but small: $\beta_a = -7\,10^{-4}$.

Finally, analyzing both Tables 12 and 13 leads to the remark that substitution effects are still present and significant in periods with a high price.

However, on Figure 8 that exhibits the pattern of purchases after a price reduction, there is some kind of decreasing pattern. Yet the magnitude of such an effect is about -0.0125 units per week and per store, which accounts for 1% of quantities sold only. As a result, there is some asymmetry between what happens before and what happens after a price reduction. Moreover, consumers may be heterogeneous in the way they form their expectations: a small fraction of the population might have better expectations about the price process than others. Finally, this can also be due to the fact that stores do not change labels on albums after a price reduction.

One might worry whether these results are robust to the subdivision of albums according to their n. This is done in Appendix (Table 15) and yields roughly the same diagnosis.



(a) price reductions (PR) (b) sales only (S)

Figure 8: Evidence of imperfect expectations - 2

At the end, we believe that the effect pointed out by Figure 8 is still too weak to suggest that consumers use a time independent information set to make their decision. A small fraction of consumers would truly update their beliefs as time goes by, mainly remembering after a price reduction that they have better wait for the next one. Globally, we accept Prediction 2. Our data look thus qualitatively like Figure 3 or 4: they exhibit a flat pattern when prices are high, and a peak of demand at the beginning of a price reduction.

5.3 Dynamic decisions based on a time independent information set

Fact 4 *When the price is high, the demand decreases with the price gap, the gap between the current price and the price that is charged during a price reduction.*

Fourth, to reject myopic behavior, we propose to show Fact 4 which indicates some strategic behavior. According to Prediction 3, a myopic demand should not be affected by anything but the current price, and especially be independent from the price gap $\overline{p}-\underline{p}$. This is in contrast to what happens when some information is used to form expectations, and when consumers wait more when they expect a higher price gap, which decreases the demand when the price is high. We perform the following regression:

$$q_{jrt} = \gamma \Delta p_{jrt} + \beta_x X_{jrt} + \xi_{jr} + \delta_t + \epsilon_{jrt} \tag{10}$$

Since *before* and *after* turned out to be not significant, we omit them from the regression; including them in the set of covariates does not alter the result.

In Table 14, we test and reject $H_0 : \gamma = 0$ at the 5% level. We find that $\gamma = -0.016$; its negative sign indicates that there is some strategic delaying of purchases. When the expected price gap is higher, more consumers wait and thus the current demand decreases. We notice that the substitution effects remain stable. As a result, consumers do take dynamic decisions of purchase and are neither completely informed nor completely uninformed about the future in this market. They hold rather wrong expectations about prices since correct expectations have already been rejected. To check whether this intermediate situation corresponds to the case described by Prediction 4, we document then the following.

Fact 5 *When the price is high, the demand decreases with the ratio between the price gap and the length of the interval between two price reductions.*

We eventually perform the following regression:

$$q_{jrt} = \gamma_n \frac{\Delta p_{jrt}}{\overline{n}_{jr}} + \beta_x X_{jrt} + \xi_{jr} + \delta_t + \epsilon_{jrt} \tag{11}$$

Table 14: Demand when the price is high

	Purchases q_{jrt}	
price gap	-0.016^{***} (0.003)	.
price gap/n	.	-0.430^{***} (0.091)
nb albums on sale	-0.004^{**} (0.002)	-0.004^{**} (0.002)
nb albums same author	-0.004^{**} (0.002)	-0.004^{**} (0.002)
Album-store effects ξ_{jr}	Yes	Yes
Time effects	Yes	Yes
Variance due to ξ_{jr}	0.80	0.80
Number of observations	85,359	85,359

To see why the information set that is used to form expectations over future prices does not vary over time, we consider the ratio between the price gap and the interval between two price reductions denoted n in the model from Section 2. According to the time independent information hypothesis, the demand must decrease with this ratio that measures simply the gain from waiting until the next price reduction with respect to immediate purchase. Such a ratio encompasses the strategic effect when consumers have simple expectations of the form described by Equation 5: consumers expecting a higher price gap or a lower duration between price cuts should delay more their purchases, which decreases the current demand.

An empirical issue is to determine the relevant n. Put differently, we suspect the interval between price reductions n to be endogenous. Note that this contrasts with $\underline{p}$ (and thus Δp) which are very likely to be correlated to the album-store fixed effect ξ_{jr} but not to the current shock of demand ϵ_{jrt}. However, popular albums are likely to have a high n and episodic (shorter) sales with low prices, which is in line with what a rational firm would do to maximize profits. To overcome this issue, we decide to take for every album-store the mean of the intervals n_{jrt} over all their observed relevant "high-then-low" sequences s $\overline{n}_{jr} = \frac{1}{S}\sum_{s=1}^{S} n_{jrt(s)}$. It is likely that $\overline{n}_{jr}$ has reduced this endogeneity issue.

Results are displayed by Table 14 and show that γ_n is about -0.43 and significant at usual levels. We find thus evidence in favor of Fact 5.

Everything happens as if consumers had in mind an average length between price reductions and formed simple expectations based on this static information, from which they take dynamic decisions. Put in other words, dynamic actions seem to rely on time independent information.

6 Discussion

6.1 Possible explanations

Indeed, behavioral economics suggests that consumer's rationality may be bounded because of limited capacity or limited memory: consumers may be far from *homo oeconomicus* and their behavior could actually look much simpler than a complex dynamic optimization. The validity of the full rationality hypothesis has often been challenged. Simon (1955) wished to replace *homo oeconomicus* with a man with bounded rationality and a whole part of the literature since Allais (1953) tries to check whether human behavior is conform to what is commonly assumed. Temptation and self-control (Gul and Pesendorfer (2001)), time inconsistency (Thaler and Shefrin (1981)) or hyperbolic discounting (Laibson (1997), O'Donoghue and Rabin (1999)) are evidence of non-fully rational behavior and have been widely documented through lotteries or experiments. Ellison (2006) already pointed out that bounded rationality matters in industrial organization.

On the one hand, the bounded rationality theory emphasizes that consumers may be unable or unwilling to do all the computations required. It suggests that their ability to optimize is limited. As documented by Vriend (1996), "agents capabilities are constrained by perception, logical power and economic capacity". This theory recognizes the role played by heuristics and stresses the existence of psychological biases, of the *rule-of-thumb* interfering with the rational decision process. This is the *limited capacity* explanation proposed by Simon (1955) who suggested that consumers stopped their optimization at the first *satisficing* solution reached. On the other hand, consumers may have a *limited* *memory*: they do optimize but might do it on a restricted information set, reaching therefore a second-best solution. This imperfect monitoring of the state of the world is likely to happen because human beings considered as physical objects are intrinsically limited in the amount of information they can receive. Another explanation for the limited memory hypothesis is that information is costly to gather – and thus valuable. The role of information was emphasized first by Stigler (1961) who inspires models with search costs. Consumers facing such costs decide to acquire information only when it is profitable for them to do so. As a result, consumers may decide not to collect further information, which bounds their memory *de facto*. In the model of Reis (2006) for instance, consumers are *inattentive* in the sense that in multi-periods games they decide not to pay attention to prices every period. Finally, consumers may also forget the past.

Moreover, heterogeneity among consumers' degree of rationality matters. Some consumers may have no information on past prices, which prevents them from forming correct expectations: this may be the case of occasional shoppers; or they have access to information as regular shoppers do, but they are not able to manage such an information set and restrict their analysis to a smaller set. Some theoretical papers had introduced naive and sophisticated consumers. Varian (1980) invokes heterogeneous search costs to distinguish among informed and uninformed consumers who have a limited information set. This idea was also considered by Pesendorfer (2002) who distinguishes loyal consumers from shoppers. Sobel (1984) considers that some part of the population cannot delay strategically their purchase because of limited capacity. These forms of imperfect rationality are however not able to fully rationalize the results obtained in this paper.

6.2 Implications

In this market, consumers behave as if they were expecting a Markov process for prices. Indeed, the scenario that corresponds the most to consumers' behavior is the one where consumers expect a price reduction with a constant probability over time, that is $\mathbb{E}(p_{t+1}|p_t = \overline{p}) = (1-\lambda)p_t + \lambda \underline{p}$. This Markov assumption is often made in the literature devoted to the structural estimation of dynamic discrete-choice models (DDCM) like Hendel and Nevo (2006) and Gowrisankaran and Rysman (2011). It is somehow considered as an approximation of a true consumer's behavior having perfect foresight. Yet it entails a significant reduction of the computational burden. We showed that such an assumption can be tested, and how we accepted this hypothesis in our market.

Making the assumption of once-for-all expectations *versus* perfect foresight or rational expectations may impact the demand function, the computation of the firm's optimal policy and thus on welfare. A step in this direction that is left for further research would be to estimate a structural model of demand relying on this assumption and compare results obtained under myopia or perfect foresight.

6.3 Limits

First, these results are specific to the music industry and concern only a segment of consumers who are loyal to the chain considered. They may sound not too much surprising since the catalogue and thus the information set are large, and remembering past prices for all albums would be rather demanding in this context.

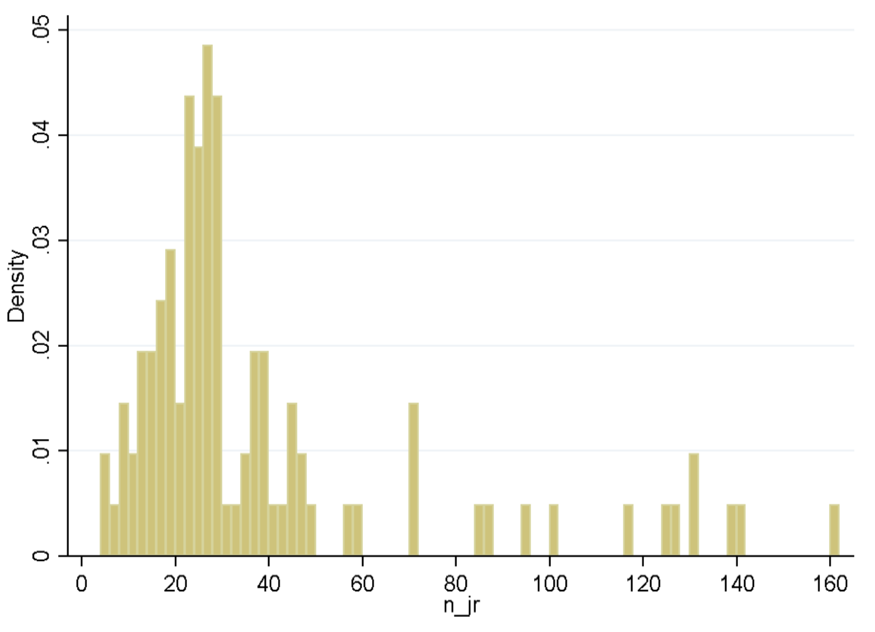


Figure 9: Heterogeneity of average durations between price reductions

In this vein, there is no clear seasonality in the timing of such promotions: every week, about 7.5% of albums have a sale. There is no clear increase of sales immediately before, during or after Christmas. As a result, anticipating sales is not an easy task. Each album has its own price cycle: the average interval between two promotions is distributed according to Figure 9. Even though there is a mode at about 28 weeks, there is a whole distribution of these durations. This complicates predictions of future price falls that consumers can make: consumers simply cannot remember all price cycles for the whole set of albums. Nevertheless, since the probability of a price reduction always increases with the elapsed duration since the last price reduction as will be shown next, consumers holding rational expectations should take it into account and some decreasing pattern should be observed.

Third, in other industries like clothing, where sales have a fixed and public schedule (at the beginning of January and June in France), it would actually be interesting to perform the same test. Consumers would be almost all informed and may only differ in their ability (or willingness) to optimize, which would enable to disentangle the limited memory from the limited capacity effect. Similarly, consumers are more likely to be optimizers and to form correct beliefs for housing or for cars where more substantial amounts of money are involved. Chevalier and Goolsbee (2009) for instance have a similar test in nature but distinct in practice for college textbooks: they accept the idea that students are forward-looking, which can be explained by the fact that students are rather optimizers.

Fourth, competition is absent from the current analysis. However, it is hard to imagine that the flat pattern is caused by the fact that consumers go systematically more to the competitor(s) at the beginning than at the end of a period with high prices.

Finally, one could imagine other explanations for the flat pattern. For instance, cohorts of consumers could be heterogeneous. In case when they are more numerous before price reductions, there could be a decreasing pattern coming from time dependent expectations exactly compensated by an increasing pattern due to the size of cohorts. However, this should hold for every price reduction, given that these price reductions are specific to some album-store and do not all occur at the same time.

7 Conclusion

To conclude, this paper has tested usual assumptions about agents expectations and dynamic behavior using market-level data. Strategic consumers with perfect foresight or revising correctly their beliefs would delay more and more their purchase as the price reduction approaches; consumers with once-for-all expectations would not behave like this, which generates a declining pattern of purchases when the price is constantly high in the former case, and a constant pattern in the latter, which should be observed in the data. On our data, we test and accept the hypothesis of once-for-all expectations. Similarly, the firm may fix prices in a more or less dynamic fashion, and here her behavior is close to what an optimal firm would do.

These results are coherent with rational consumers expecting a simple though wrong Markov price process. Though this may not be surprising in this setting, we believe that such a test could easily be performed before the estimation of structural DDCM models since it reinsures about the validity of assumptions regarding agents rationality. Moreover, if these results do not affect the estimation of dynamic models of demand that already rely on a Markov assumption for the price process, they do impact the firm's equilibrium price strategy and the welfare analysis as well.

A natural extension would consist in measuring the loss caused by this lack of anticipation: facing the same price process, how would consumers with correct beliefs behave? Another interesting question would be to compute the equilibrium of the game in which both the firm and consumers are fully rational, and compare it with the observed one.

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A List of albums

AUTHOR	TITLE	SALES	AUTHOR	TITLE	SALES
YOUNG	harvest	17727	SUPERTRAMP	verybestofvol1	2712
QUEEN	platinumcollection	15457	RAGEAGAINSTTHEMACHINE	bombtrack	2661
CHAPMAN	tracychapman	14271	RIVERS	johnleehooker	2564
DIDO	noangel	14264	SCORPIONS	bestof	2451
DOORS	doors	11174	PATRICE	ancientspirit	2426
NIRVANA	nevermind	9989	SUPERTRAMP	breakfastinamerica	2417
LEDZEPPELIN	ledzeppeliniv	9831	MARILYNMANSON	antichristsuperstar	2390
VELVETUNDERGROUND	andywarhol	9686	SLIPKNOT	slipknot	2382
THECLASH	londoncalling	9671	POLICE	reggattadeblanc	2366
HARPER	welcometothecruelworl	9565	MARILYNMANSON	holywood	2354
SYSTEMOFADOWN	toxicity	9155	SIMPLYRED	greatesthits	2335
COLDPLAY	parachutes	9150	U2	joshuatree	2311
PINKFLOYD	darksideofthemoon	9116	U2	war	2294
BEATLES	one	8610	OASIS	morningglorywhatsthe	2293
DOORS	lawoman	8601	DEPECHEMODE	101live	2186
LEDZEPPELIN	ledzeppelinii	8082	RAMMSTEIN	liveausberlin	2006
CASAL	luzcasal	7175	MARILYNMANSON	mechanicalanimals	1975
NIRVANA	unpluggedinnewyork	7014	TOURNEEEUROPEENNE1	live	1970
PINKFLOYD	wall	6913	VAYACONDIOS	bestof	1944
LEDZEPPELIN	ledzeppelini	6913	WYATT	rockbottom	1940
BUCKLEY	livealolympia1995	6846	COHEN	greatesthits	1829
SEXPISTOLS	nevermindthebollocks	6801	MARILYNMANSON	smellslikechildren	1826
JOPLIN	greatesthits	6747	QUEEN	anightattheopera	1768
MADONNA	immaculatecollection	6712	POP	lustforlife	1761
PINKFLOYD	wall	6550	SINATRA	mywaythebestoffrank	1748
ABBA	abbagold	6393	BLUESBROTHERS	verybestof	1722
EAGLES	hotelcalifornia	6286	IRONMAIDEN	numberofthebeast	1720
LEDZEPPELIN	ledzeppeliniii	5971	LEDZEPPELIN	remastersvol1	1687
HARPER	fightforyourmind	5557	METALLICA	sanfranciscosymphonyor	1683
CONTE	bestof	5485	JOPLIN	pearl	1679
PINKFLOYD	wishyouwerehere	5324	CROSBYSTILLSANDNASH	dejavu	1659
LOVE	foreverchanges	5248	DOORS	bestof	1586
COLLINS	hits	5205	PINKFLOYD	more	1565
REDHOTCHILIPEPPERS	californication	5202	SMITH	easter	1552
PINKFLOYD	atomheartmother	5201	REED	berlin	1495
BOBDYLAN	essentialbobdylan	4945	ZZTOP	greatesthits	1413
SYSTEMOFADOWN	systemofadown	4909	KSCHOICE	paradiseinme	1408
BEATLES	bleu19671970	4508	BEATLES	rubbersoul	1362
DOORS	waitingforthesun	4402	WAITS	mulevariations	1298
WHO	whosnextremasterise7	4346	HENDRIX	axisboldaslove	1291
SMITHS	queenisdead	4189	SIMPLEMINDS	liveinthecityoflight	1276
DEEPPURPLE	madeinjapan	4091	MADONNA	ultimatecollection	1269
BEATLES	sergentpepperslonelyh	3988	POGUES	verybestof	1260
BEATLES	whitealbum2cd	3912	SANTANA	abraxas	1216
MADONNA	music	3904	WHO	liveatleeds	1210
BEATLES	rouge19621966	3736	QUEEN	newsoftheworld	1164
RAMMSTEIN	mutter	3676	SOMERVILLE	greatesthits	1092
CLAPTON	unplugged	3570	MAMASANDTHEPAPAS	verybestof	1042
BEATLES	abbeyroad	3499	BEATLES	help	1033
HENDRIX	electricladyland	3468	MARILYNMANSON	lasttour	1019
PINKFLOYD	meddle	3367	QUEEN	innuendo	997
HENDRIX	experiencehendrix	3319	NOMI	20plusbelleschansons	980
DIRESTRAITS	brothersinarms	3233	MARILYNMANSON	portraitofanamericanf	905
PINKFLOYD	animals	3167	QUEEN	livemagic	816
REDHOTCHILIPEPPERS	bloodsugarsexmagik	3154	KNOPFLER	sailingtophiladelphia	772
HARPER	willtolive	3144	TYLER	bestof	758
STEVENS	teaforthetillerman	3132	ZAPPA	hotrats	685
ROLLINGSTONES	flashpoint	3054	BUCKLEY	sketches	639
RAMAZZOTTI	eros	3021	CARPENTERS	gold	588
MADNESS	onestepbeyond	2839	KNOPFLER	neckandneck	504
JETHROTULL	aqualung	2742			

B Imputation of prices and smoothing

We describe here the issue of recovering prices when they are not observed because there is no purchase.

– Step 0: From daily to weekly

We aggregate daily to weekly observations through the procedure followed by Pesendorfer (2002) using data from the Chicago Booth GSB. Basically, the weekly price will correspond to the "most frequent" price of the week, "most frequent" being weighted by the amount of purchases. We restrict our attention to the subsample of albums that are sold at least once during the two first and last months in every big French store; the price of such albums should exceed 2 euros. We are left with 1207 albums-stores during 203 weeks *i.e.* $245,021$ observations.

– Step 1: Defining regular prices

For every album-store we define a set of regular prices based on observed prices as the subset of prices that were charged at least three – non necessarily consecutive – weeks during the whole period. An album–store can have between 1 and 15 of such prices.

– Step 2: Imputing regular prices

We impute the closest higher regular price to any observed price, provided that the difference is larger than the maximum of 20 cents or 2% of the price, when we impute the closest lower regular price.

– Step 3: Imputing missing prices

Then we impute missing prices (a "zero") using these regular prices.

– Step 3a: When there is either a one-week ($20,628$ observations) or a two-week zero ($17,636$ observations), we impute the maximum adjacent price.

– Step 3b: For longer periods of zeroes ($73,205$ observations), we impute the most frequent price at the nationwide level for this album when it is available and when it belongs to the set of regular prices defined at the album–store level.

– Step 3c: In the other cases ($5,230$ observations), we impute the maximum adjacent price.

– Step 4: Smoothing

We smooth these price patterns by first eliminating one–week price changes and then second–week price changes. We thus replace observed or imputed prices by the closest adjacent price in such cases.

Table 15: Demand when the price is high

	Purchases q_{jrt}							
	$3 \leq n \leq 7$	$8 \leq n \leq 13$	$14 \leq n \leq 19$	$20 \leq n \leq 25$	$26 \leq n \leq 31$	$32 \leq n \leq 37]$	$38 \leq n \leq 43$	$44 \leq n \leq 49$
before	-0.058	-0.006	0.027^{***}	0.013^{***}	-0.013^{***}	-0.007^{**}	0.010^{***}	0.006^{*}
	(0.040)	(0.012)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
after	0.071^{*}	0.002	-0.030^{***}	-0.012^{***}	0.013^{***}	0.006^{**}	-0.010^{***}	-0.006^{*}
	(0.039)	(0.012)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Album-store effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	1,485	4,380	9,800	7,999	5,654	9,463	8,108	5,521

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