Information Saves Money: Efficiency and Obsolescence of Consumer Price Information

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Abstract

We analyze how profitable is for a consumer to spend resources searching for prices at stores, by using the distribution of prices in a certain time period as the only source of information. Applying the statistical theory of extreme values, we have developed a methodology to measure the efficiency and obsolescence of a set of price information. We have found that if a consumer searches for a second price, he will get an average marginal saving of 8.25%; for a third price, a 3.4% will be added, and so on. A perfectly well informed consumer (who knows all prices) will save an average of 24%. But this information will quickly become obsolete because sellers continuously change their prices and relative ranking into the price distribution. We have estimated that, after six months, a 60% of consumers' information will be outdated. This result would force consumers to a continuous searching process to update their price information.

Keywords: Information Efficiency, Obsolescence, and Prices.

JEL: D40, D46

INTRODUCTION

The economics of information studies reasons why consumers take the decision of searching for lower prices. Since Stigler's paper on the economics of information (1961), many studies have arrived at the same conclusion: the more information consumers have on product prices before buying, the lower the equilibrium prices that will be set by sellers, thus the market will be more efficient [in theoretical terms, Varian (1980), Burdett and Judd (1983), Stahl (1989); and in empirical terms, Sorensen (2000), Hortaçsu and Syverson (2004) and Brown and Goolsbee (2002)]. The idea underlying this belief is as follows: in principle, the consumer, faced with homogeneous goods, will purchase in the lowest-price establishment known; thus, the more stores visited (or for which information is available about the prices charged) the more likely that purchases will be made at a lower price. Therefore, the more prices are known to the consumer, the lower the prices he will expect to pay.

From the Theory of information point of view, the higher the expected savings, the more researches consumers would do. One characteristic of empirical models explaining consumers' price-search behavior is that take only characteristics and attitude of the consumers into account. These models do not use enough information on the market that affects how many searches consumers will perform.

We wonder, do all the markets encourage to the consumer to search for lower prices the same way? Some authors have pointed out that factor as the shopping frequency, the frequency of changing prices in the market, the existence of cheap/expensive stores, geo-economical location of stores, etc. affect the price-search behavior.

All these mentioned factor, jointly with others, define the main characteristics of the distribution of prices in a market at a certain period of time. So, the distribution of prices has relevant information for consumers' decision of how many searches will do. Thus, model based on the

Theory of information should get the information of the distribution of prices into it. Nevertheless, we have not found any research focused on the distribution of prices as key information on the consumers' price-search decision.

To narrow this gap, in the present paper we analyze how profitable is for consumers expending resources searching for prices, using the distribution of prices itself as the only source of information, with no preference for any store which sell a perfectly homogeneous product. The key point is, if consumers could save money as a consequence of searching the market, they would have incentives to do so, pushing prices down.

The rest of this paper is structured in four parts: the following section presents the theory underlying this study of price distributions and the approach taken to estimating the effect of consumers' search for information. In the second section we describe the sample data, after which, section three presents and discusses our findings on information efficiency and its obsolescence, measured for the Canary Islands market. Finally, section four sets out the main conclusions reached.

METHODOLOGY

Our starting point is a consumer willing to buy a product in a completely unknown market. Products are fully homogeneous (brand, packaging, quality, etc.…) and there is no transaction costs. The consumer's decision will be only based on the selling prices of each store. Let p be the price of the product, F(p) and f(p) the distribution and density function, respectively.

Whether the consumer has no information and randomly chooses one store, the average price he would pay is the average of the distribution of prices. Let $\mu(1)$ be that average, being 1 the number of prices known by the consumer before buying the product. In the opposite extreme, the consumer who knows all the prices will pay the minimum price, i.e. $\mu(\infty) = p_{\min}$. If the consumer decides to research two stores and then buying in the cheaper one, he would have an average of $\mu(2)$ that will be equal or less than $\mu(1)$. The average saving of this second search will be, in absolute term, $\mu(1)-\mu(2)$, and a ratio of $a_2 = \dfrac{\mu(2)-\mu(1)}{\mu(1)}$.

A consumer who knows n prices will pay the minimum of the set $\{p_1, p_2, ..., p_n\}$. Let P that price, following the extreme value theory [Gumbel (1954), Coles (2001), Albeverio et al. (2005), etc...], the distribution function of extreme value, G(P), is calculated according to (1).

$$G(P) = 1 - \text{Prob}\left[(p_1 > P) \cap (p_2 > P) \cap ... \cap (p_n > P)\right] \tag{1}$$

To calculate this probability distribution, we must do some assumptions about how the consumer obtains information. In the initial scenario, consumer faces a totally unknown market, and before buying an item, searches for the price offered in n randomly selected establishments. In this case, the set of prices $p_1, p_2, ..., p_n$ corresponds to a simple random sample and expression (1) is reduced to the distribution function shown in (2), where $F(\cdot)$ is the distribution function of the prices offered.

$$G(P) = 1 - \left[1 - F(P)\right]^n \tag{2}$$

The corresponding density function is calculated by (3)

$$g(P) = n\left[1 - F(P)\right]^{n-1} f(P) \tag{3}$$

From (3) we can calculate the average prices that consumers' pay and the average saving, conditional on the number of known prices. More precisely, $a_n = \dfrac{\mu(n)-\mu(1)}{\mu(1)}$ is the average saving of searching for n prices instead of one. The total or maximum saving is obtained when all prices are known and, in that case, consumer will pay the minimum price, so its expression is $a_\infty = \dfrac{P_{\min}-\mu(1)}{\mu(1)}$.

From both expressions, we derive the saving multiplier due to the n known prices as the difference $a_n - a_{n-1}$. We can study the average saving using the distribution of information efficiency, where its modalities are the number of searches (n) and its frequencies h(n) are:

$$h(n) = \frac{a_n - a_{n-1}}{a_\infty} \tag{4}$$

h(n) measures the saving effect of knowing an additional price divided by the total saving, i.e. the marginal effect of one more search. For example, h(2)=0.3 means that if a consumer searched for a second price when knowing one, he would save an average 30% of the total saving he would get searching for all the prices.

The knowledge of this distribution is essential for the consumer to decide how many searches to be done before buying the product. Moreover, the lesser dependence this distribution has of prices, the more relevance its knowledge will have for a consumer. Mainly because this information could be used for another product, or for the same product in another market, when the total savings are equals.

Two main reasons show h(n) importance, firstly, it estimates the average saving for researching one more price, and secondly, it can be used to differentiate between markets. Distribution of prices is the result of all the actions of the agents of the market, so its form is the reflection of equilibrium. h(n) is a measure of this equilibrium, so that, if two markets have the same values of h(n), they could be called similar. As the equilibrium between market agents' forces define its competiveness, the value of h(n) is related to the degree of competiveness of the markets.

1.1. The efficiency of information in a market with uniformly distributed prices

Uniformly distributed prices are a limit case. In this distribution the minimum price is one of its parameters, which implies that the distribution of efficiency is unique, as it can be seen in (10).

Assuming that prices are uniformly distributed with positive parameters a and b, i.e. $p \to U(a,b)$. It can be easily shown that:

a. If the consumer knows n prices, the average price he will pay is (5)

$$\mu(n) = b - \frac{n}{n+1}(b-a) \tag{5}$$

b. The average saving ratio of knowing n prices instead of one is (6)

$$a_n = \frac{\mu(n)-\mu(1)}{\mu(1)} = \frac{\sigma(1)}{\mu(1)} * \frac{\sqrt{12}*(1-n)}{2*(1+n)} = [CV] * \frac{\sqrt{12}*(1-n)}{2*(1+n)}, \forall n \geq 2 \tag{6}$$

being CV the coefficient of variation (ratio between the mean and the standard deviation) of the distribution of prices. This savings can be re-written as (7)

$$a_n = [CV] * \beta_n \text{, with } \beta_n = \frac{\sqrt{12}*(1-n)}{2*(1+n)}; n \geq 2 \tag{7}$$

c. The maximum average saving can be calculated as in (8)

$$a_\infty = \frac{a-b}{a+b} \tag{8}$$

The key element in the amount of the saving is the relative dispersion of prices. Calculations of the distribution of these savings, as a function of the n known prices h(n), are determined by the set $\{\beta_n\}$. Expression (4) can be simplified as in (9)

$$h(n) = \frac{a_n - a_{n-1}}{a_\infty} = \frac{\beta_n CV - \beta_{n-1} CV}{\beta_\infty CV} = \frac{\beta_n - \beta_{n-1}}{\beta_\infty} \tag{9}$$

using (7) and (8), we can conclude that $\beta_\infty = \frac{\sqrt{12}}{2}$, and finally, h(n) only depends on the number of known prices (10)

$$h(n) = \frac{2}{(n+1)*n} \tag{10}$$

It is important to point out that expression (10) does not depend on prices; product or market and its values are shown in Table 1. If prices are uniformly distributed, this expression (10) measures the marginal saving ratio of one more search, i.e., it is the elasticity of saving for search. For example, a 33,33% of the total average saving is obtained after searching for a second price. A third price adds a 16,66%, leading to an accumulative 50%.

Table 1. Distribution of the efficiency of consumer research, when prices are uniformly distributed

Number of searches *(n)*	$h(n)$
1	---
2	0,33333
3	0,16667
4	0,10000
5	0,06667
6	0,04762
7	0,03571
8	0,02778

1.2. Information efficiency in a market with normally distributed prices

Assuming that prices are normally distributed with mean μ and standard deviation σ, Stigler (1961) obtained the average prices the consumer would pay, taking into account the number of stores visited before making the purchase. It is straightforward to show (11) but with different values of β_n, which can be derived as in Stigler (1961), β_2=0.564, β_3=0.846, β_4=1.029, β_5=1.163, etc.,

$$a_{n/1} = -\beta_{n/1} * CV \qquad (11)$$

Inasmuch as betas are unique for every normal distribution, the distribution of information efficiency depends only on the minimum price. Nevertheless, as β_n are fixed values, estimation of the distribution of information efficiency needs an estimation of β_∞. Taking (11) into account, the latter coincides with the standardized minimum price.

$$\beta_\infty = \frac{P_{\min} - \mu(1)}{\sigma(1)} \tag{12}$$

1.3 Needed assumptions to estimate the distribution of the efficiency of consumer research

The little knowledge on the distribution of prices makes difficult to estimate the distribution of information efficiency. Nevertheless, under the assumption of (11), the values of β_n depend only on the form of the distribution, and β_∞ is still the standardized minimum price. If a sample of prices were available, density function (3) and β_n can be estimated as in (11).

1.4. Obsolescence of Price Information

A second question to be considered on analyzing information efficiency concerns its durability over time. In other words, the longer this information lasting useful, the higher the motivation for a consumer to look for new price information

Clearly, the more changes in the distribution of prices for a product from one moment of time to another, the less useful the information is. But, even if the distribution is the same at both time points, the efficiency of the information depends on where each store (and its price) is ranked in the distribution. For example, if the distribution of prices were the same at moments *t* and *t'*, but the more expensive stores at time *t* are cheaper at time *t'* and vice versa, then the information available to the consumer at *t* is not valid at *t'*. Conversely, if the price distributions and pricing policies of the stores are equal for any instant of time, the information obtained by the consumer will never become obsolete. Moreover, even if price distributions change between two points of time, as long as the relative positioning of stores' pricing policies remains constant, then the pricing information will remain valid for subsequent instants of time.

DATA

We have analyzed retail prices for repetitive consumer products within an idiosyncratic market, comprised of the seven islands that make up the Canary archipelago. Prices came from products in the categories of food, personal hygiene and household cleaning. The database contains 1,387,293 unpublished prices obtained by ISTAC[1] to compile the statistical operation "Household Price Survey - Canary Islands". All prices refer to frequently purchased goods. In terms of consumption, using INE [2] weighting data for 2007, these products accounted for 28.36% of total household consumption in the Canaries, which makes this database the largest such analyzed to date for this population and consumer group.

For each price the following data are available:

- The month and year it was observed, with a maximum time period from September 2003 to February 2010 inclusive.

- The code of the establishment where the price was observed. In total, data were obtained from 174 establishments. The exact geographical locations of the establishments are not stated, but the island on which each is located is given. There are two types of establishments: Type 1, large stores, hypermarkets, supermarkets and traditional shops. These establishments all offer a wide range of food, personal hygiene and household cleaning products. On the other hand, the Type 2 establishments are specialized and only offer products for some of the areas specified.

- The corresponding product code. A total of 251 products were sampled, each of which was unambiguously identified. The price analysis, however, was performed on the basis of 14 groups (Appendix). In each of the Type 1 establishments, all the products were sampled, whereas in the Type 2 shops, between 10 and 20 were sampled. Finally, 88 Type 1 and 86 Type 2 establishments were included. Not all products were sampled in both types of establishment. 209 products,

[1] ISTAC, Canary Islands Institute of Statistics
[2] INE, Spanish National Institute of Statistics

corresponding to group 1-10, were only measured in Type 1 establishments. The remaining 42 products, in groups 11-14, were sampled in both types of establishment.

After cleaning the database on incongruences, outliers, and limiting to distributions prices with more than 20 data, those restrictions imply 21.605 distributions with a maximum of 82 data.

Table 1 shows that most of these distributions have a relative dispersion (standard deviation over mean) below 30%, are generally symmetrically positive and present a great variability on their kurtosis. Also, there is some association between extreme values of asymmetry and relative dispersion, and between extreme values of kurtosis and the most symmetrical distributions.

Table 1. Distributions of prices. Descriptive analysis.

Relative dispersion	Frequency	Symmetry	Frequency	Kurtosis	Frequency
[0-0,1)	22,64%	[-8, -6)	0,04%	[-2, -1)	14,1%
[0,1-0,2)	43,66%	[-6, -4)	0,08%	[-1, 0)	30,6%
[0,2-0,3)	22,89%	[-4, -2)	1,1%	[0, 1)	20,22%
[0,3-0,4)	8,01%	[-2, 0)	23,29%	[1, 2)	11,81%
[0,4-0,5)	2,15%	[0, 2)	65,8%	[2, 5)	14,61%
[0,5-1]	0,65%	[2, 8)	9,69%	[5, 53)	8,67%

We have computed the ratio between the minimum and maximum price of every distribution in the sample. The mean of this ratio is 2 and the median is 1.8, meaning that the maximum price is, in average, the double of the minimum price, and in the 50% of the distributions, the maximum price is, at least, an 80% higher than the minimum price. By island, Gran Canaria and Tenerife have significant higher means. By family of products, fresh vegetables and fishes are statistically higher with means over three.

RESULTS AND DISCUSSION

Using expressions (2) and (3), we have estimated the distributions of prices based on the number of searches (equivalent to the number of known prices) and their average prices $\mu(n)$. The maximum number of searches, in the present paper, is 20. Lastly, expression (13) allows the estimation of the average saving of searching n prices instead compared to one, (14) the values of β_n and, (15) the frequencies of the distribution on information efficiency.

$$\hat{a}_n = \frac{\hat{\mu}(n) - \hat{\mu}(1)}{\hat{\mu}(1)} \tag{13}$$

$$\hat{\beta}_n = \frac{\hat{\mu}(n) - \hat{\mu}(1)}{\hat{\sigma}(1)} \tag{14}$$

$$\hat{h}(n) = \frac{\hat{\mu}(n) - \hat{\mu}(n-1)}{P_{\min} - \hat{\mu}(1)} \tag{15}$$

In the figure 1, we have presented the average values of h(n) of all the estimated distributions of prices from n=2 to 8. The point inside the box is the average, the line inside is the median, lower and upper limits of the box are the first and third quartile, respectively. Circles and asterisks outside the box are outliers. There is a high concentration at the center values for all n, and a small group of distributions with an atypical behavior.

Figure 1. Description of h(n) values

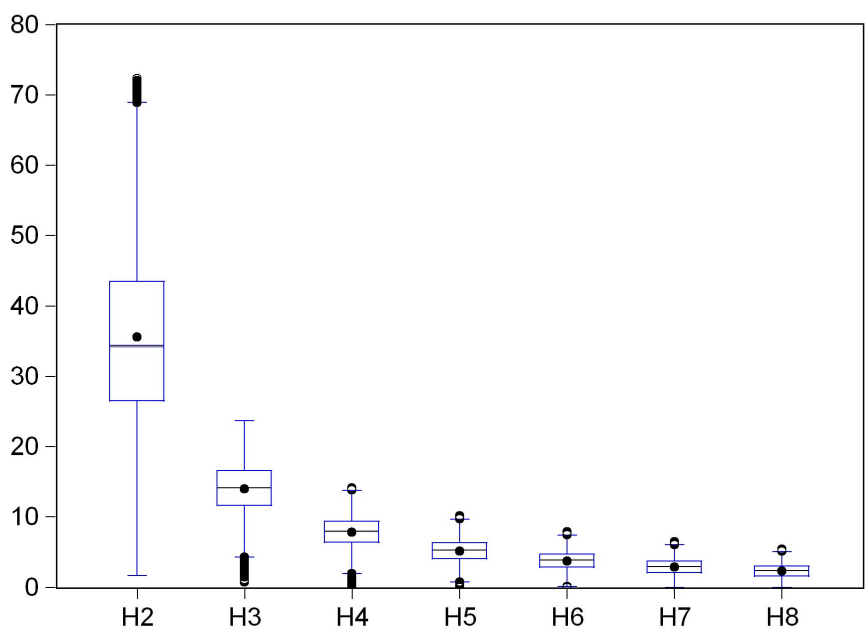


Table 2 shows the average total saving by number of researches and the median values of h(n) (the lines inside the box in Figure1)

Table 2. Distribution of information efficiency. Canary Islands median values.

Number of searches (n)	Average total saving by n (β_n)	$h(n)$
2	8.25%	34.34%
3	3.41%	14.19%
4	1.92%	7.98%
5	1.28%	5.32%
6	0.93%	3.89%
7	0.72%	3.00%
8	0.58%	2.40%
Average total saving	24.01%	100%

The median of the average total saving is 24%, meaning that a consumer with 8 researches can save that percentage. The distribution of information efficiency shows that a 34% of this average could be obtained after the second search, an additional 14% for a third one, a 7,98% for a four search, and so on. The median of the distribution of information efficiency is about three, meaning that if consumer searches for 3 prices, he would get a 50% of the total saving of knowing all the prices.

We have estimated seven regressions to test which factor affects more to the average total saving. The list of factors and the adjusted R-squared are shown in Table 3. For example, the first factor we have tested is the product, so we have estimated (16)

$$y = \alpha + \sum_{\text{Product } i=2}^{251} \beta_i P_i + \varepsilon \tag{16}$$

Both the average of total saving and the distribution of information efficiency significantly depend on the products, the islands and, in a minor way, in the trimesters.

Table 3. Adjusted R-squared. Average total saving by factor

Factor	Adjusted R-squared
Product	54.51%
Island	2.72%
Trimester	0.82%
Product*Island	56.67%
Product*Trimester	55.00%
Island*Trimester	3.50%
Product*Island*Trimester	57.12%

Analyzing the results of the last regression, the savings in the last year and a half of the sample (second half of 2008 and all the 2009) are statistically lower than in the previous years. The island effect is small but statistically significant, the bigger saving can be got in Tenerife and the smaller in Lanzarote with a difference of a 5,4%.

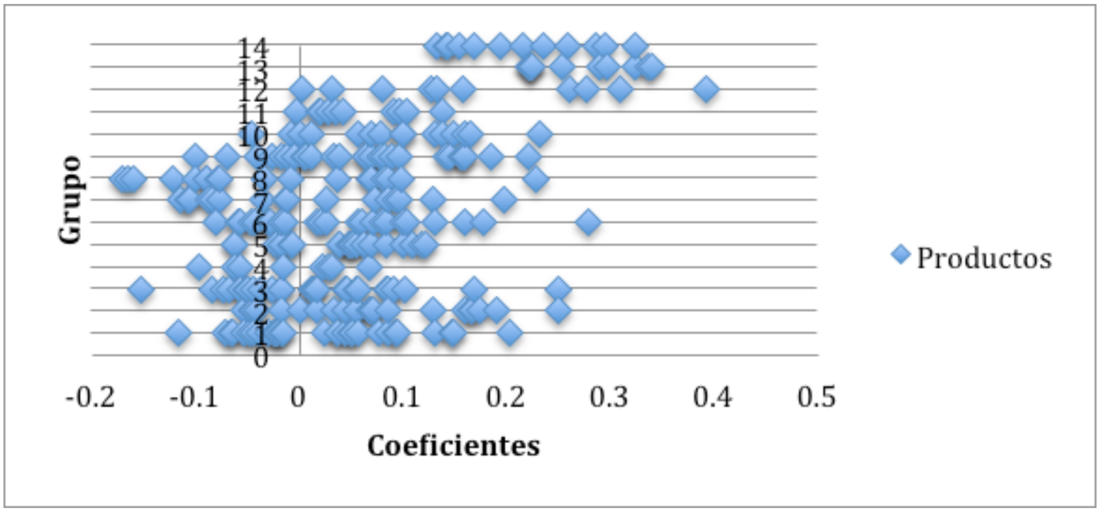
Products cause the bigger effect on savings. To make a deeper analysis we have estimated (17):

$$y = \alpha + \sum_{\text{Product } i=2}^{251} \beta_i P_i + \sum_{\text{Island } j=2}^{7} \delta_j I_j + \sum_{\text{Trimester } t=2}^{25} \gamma_t T_t + \varepsilon \tag{17}$$

Figure 2 shows the average differential effect for each product (measured by β_i in (17)), related to products in the group 1. This graph highlights the movement of products in groups 11 to 14 to the positive side, which should be interpreted as these products tend to present bigger average saving from the rest.

The behavior of these four groups could be explained because they are the only with specialized stores. So, next step is to analyze the distribution of prices by type group and store. In the group 11 “fresh meat”, and group 12 “fresh fish”, specialized stores average higher prices, with a similar dispersion and less dispersion respectively, than not specialized stores. On the other hand, in the group 13 “fresh fruits”, and group 14 “fresh vegetables”, an average lower price with less dispersion can be found at specialized stores. Empirical evidence suggests that including specialized stores in the sample significantly affects the amount of saving.

Figure 2. Relative effects of group of products on the average total savings



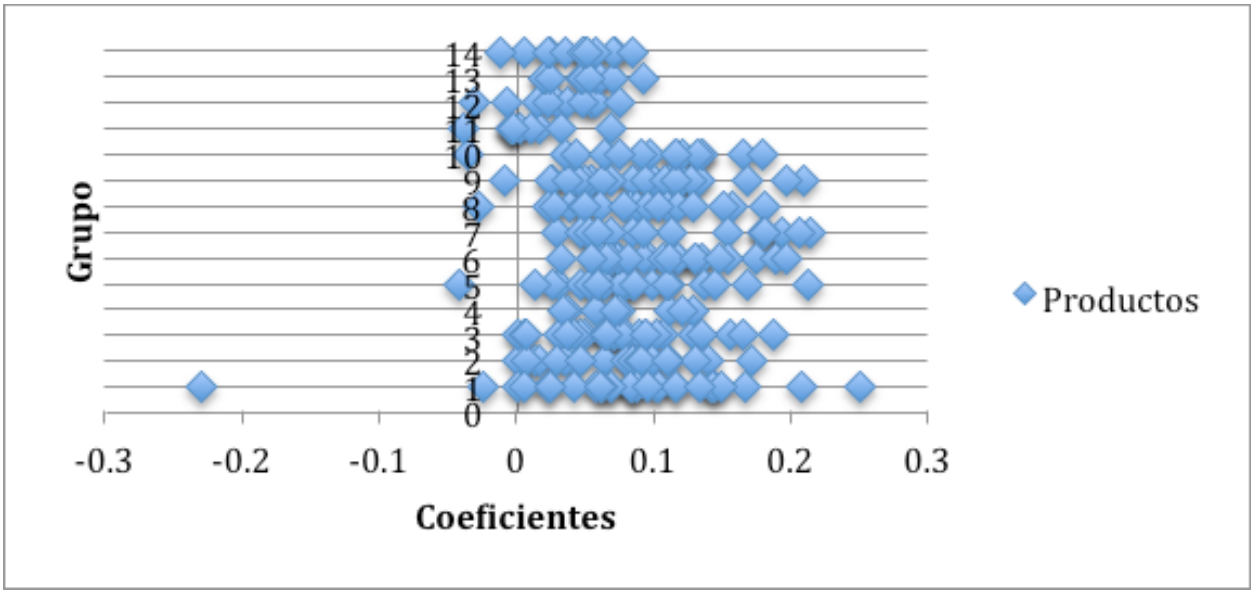
Now we have focused only in the second research, the one with the bigger effect of all. We have obtained the Table 4 and Figure3 only with the average total saving with only two researches. Comparison of Table 3 to Table 4 shows that savings with two researches are less dependent on product but higher on island and trimester than the average total saving.

Table 4. Adjusted R-squared. Values of h(2) by factor

Factors	Adjusted R-squared
Product	15.43%
Island	4.38%
Trimester	0.43%
Product*Island	17.97%
Product*Trimester	15.91%
Island*Trimester	4.80%
Product*Island*Trimester	20.45%

Figure 3 shows that fresh products (products in groups 11 to 14) have again a different behavior from the rests of products, but in contrast with Figure2, their coefficients values are smaller than the coefficients for the rest of products with only two observations. This means that consumers would obtain smaller savings with only two researches, with products in groups 11 to 14.

Figure 3. Relative effects of group of products on the average total savings for n=2



2.1. Obsolescence of price information.

¿How do points of sell react when consumers' information increases? The bigger the information amount of consumers, the more likely is buying at lower prices. Under the hypothesis of equal selling conditions, this means that consumers would buy at lower prices stores, forcing to the more expensive ones to lower their prices. At the limit point, the law of one price would fulfill, and the price would be the cheapest one.

Empirical evidence shows that this is not true. There is a distribution of prices from a set of stores selling at different prices. To adapt consumer's behavior with the existence of a distribution of prices requires that the consumer's available information have a limited time utility. This means that information is dynamic and subject to obsolescence.

Survival of stores greatly depends on their ability to make consumers' information less effective, and, in order to do so, prices are one of the main tool. In fact, empirical evidence reveals that stores change not only their nominal values, but also more important, their relative position under the distribution of prices. We have tested the latter sentence by computing the Spearman rank correlation between the distributions of prices in period t and t+m (with m=1,2,3….24 months) to analyze the evolution of correlation when monthly distance increases. A positive correlation coefficient would indicate maintaining the relative position of each store into the distribution of prices. On the other hand, a zero or negative value would suggest changes at positions within the distribution and, therefore, the usefulness of the consumers' information (obsolescence).

Table 5 shows the summary of all of these coefficients. First column is the temporal distance between compared distributions in months. Second one is the number of available samples. Third column shows the percentage of distributions with a statistically significant (at 5% level) positive correlation. It can be seen that after three months the percentage of positive correlations is below 50% and after one year falls down to 32.7%. These results imply that stores are changing their relative position, making labeling them as "cheap" or "expensive" harder for the consumers.

In short, empirical evidence shows the high degree of obsolescence of consumers' information, and the need for consumers to continuously research prices, to be more efficient taking buying decisions based on price.

Table 5. Spearman rank correlation of the distribution of prices

Time distance between distribution (months)	Number of available samples	Percentage of distributions with a statistically significant positive correlation (α=5%)
1	84943	64,0
2	83192	53,5
3	82382	48,4
4	81315	45,0
5	80202	42,4
6	79282	40,1
7	78205	38,3
8	77147	36,7
9	75990	35,3
10	74701	34,3
11	73515	33,4
12	72320	32,7
….	….	….
18	64549	28,0
….	…	….
24	57225	25,4

CONCLUSIONS

The main goal of this paper is to measure if consumers and sellers behavior affects to a more efficient market, defined as one in which price information enables the lowest possible market price. We have tested this under the assumption that the bigger the savings as information on prices grows, the greater the effort to research and that should pressure prices down. We have studied the degree of relationship between the number of researches and savings, and the degree of obsolescence of information over time.

From the theoretical point of view, we have shown that the average total saving, and the relationship of savings and the number of researches are parameters.

From the empirical point of view, we have evidence in support of the following hypothesis:

a. The average total saving for a perfectly well informed consumer has a median value of 24%, but with important variations across products. 54% of the changes in the average total savings are due to the product. Nevertheless, neither the markets (islands in the present paper) nor the time factor explain much of the variance of the average total saving, but their influence are significative. Also, there is a set of products being sold in specialized and not specialized stores. They are fresh products that are characterized by having bigger average total saving.

b. The average saving by number of researches quickly decreases when the latter increases, and it is less dependent on the products than the average total saving. The efficiency of information is very similar to that obtained by following an uniform distribution, but with savings slightly lower after more than two researches. For the Canary Islands, a 34.77% of the average total saving can be got after the second research. An additional 14.2% after the third research. After five researches, the marginal saving of one more research is less than 5% of the average total saving.

c. Sellers' pricing policies imply changes in nominal prices and their relative ranking inside the distribution of prices. These changes involve that the consumers' information is limited over time, forcing to the consumers to a continuous researching process over time. We have shown that after three month 50% of the distributions have changed.

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APPENDIX

Groups and Number of Products by Type of Establishment

Groups	Number of product	In Type I establishments	In Type II establishments
1.- Bread and cereals	29	29	0
2.- Delicatessen, meat and canned fish and preparations thereof	22	22	0
3.- Milk products, cheese and eggs	26	26	0
4.- Oils and fats	8	8	0
5.- Fruits and vegetables not fresh	20	20	0
6.- Other food products	24	24	0
7.- Non-alcoholic beverages	16	16	0
8.- Alcoholic beverages	18	18	0
9.- Non-durable household	28	28	0
10.- Personal care goods	18	18	0
11.- Fresh meat *	10	10	10
12.- Fresh fish *	10	10	10
13.- Fresh fruit *	10	10	10
14.- Fresh vegetables *	12	12	12

* Data are only available from June 2004