Repeated Price Search

A. Norman, J. Berman, K. Brehm, M. Drake, A. Dyer, J. Frisby, C. Govil, C. Hinchey, L. Heuer, J. Ke, S. Kejriwal, K. Kuang, S. Keyburn, S. Ler, K. Powers, A. Robertson, J. Sanghai, C. Schulze, J. Schieck, J. Sussman, L. Tan, A. Tello, R. Wang, K. Yan, and T. Zeinullayev

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Abstract

Consumers check few sites in online purchases. Previous research and experiments we perform demonstrate that consumers can not calculate the optimal strategy for price search. They use heuristics whose performance is better than random and less than optimal. To investigate online price search performance we survey student online textbook purchases. Students achieve good performance because they start with a good strategy and online market organization of marketplace and meta-search sites. An important factor is that algorithms at sites searched perform calculations that reduce the computational complexity of the search.

1 Introduction

In their study of the online searching of over 10,000 households, Johnson, Moe, Fader, Bellman, and Lohse (2004) find that on average consumers search less than 2 sites for books, CDs, and air travel services. In the standard one-period price search theory, for example see McMillian and Rothschild (1994), consumers are assumed to perform a price search as a random drawing with a fixed cost. They continue drawing as long as the price found is greater than the reservation price that they calculate knowing the distribution of prices. Given that the fixed cost of searching an online site is low, one would expect from this theory that consumers would search numerous online sites. The experiments of Kogut (1990) and Sonnemans (1998) show subjects draw too few times. The experimenters argue that subjects are considering the sunk costs and are not calculating a marginal cost decision based on the reservation price.

The standard one-period price search theory assumption of a random drawing ignores the fact that consumers performing repeated price searches learn and incorporate into their searches the relative prices of sellers. We investigate in several experiments how many times subjects check prices at both stores to learn the relative prices of two sellers in one, two, and four period problems. We compared the performance of two groups, one that completed a statistics course, and one that had not. In the one period problem the performance of both groups was statistically significantly better than random choice and worse than optimal. The performance of the statistics course group was statistically superior to that of the non-statistics course group. Using regression analysis we determined a heuristic explaining the performance of both groups. In the two-period Bayesian optimization problem, many subjects in

both groups demonstrated a lack of knowledge of Bayes theorem. We also studied the behavior of 25 subjects in 2 and 4 period problems. In all of the problems the subjects checked prices at both stores less than an optimal number of times and in three out of the four cases this difference was statistically significant. Can consumers achieve good price search performance by checking a small number of sites making suboptimal calculations?

To answer this question, we investigated student textbook buying behavior at the University of Texas at Austin, UT, using surveys. Students buying textbooks online also only check a small number of sites. Student price search performance is a function of market organization and how students establish and update their price search strategy. Because marketplace sites can can list several hundred sellers of popular first-year textbooks, a student only has to check a few sites to achieve good performance for different risk levels. Marketplace and meta-search sites improve consumer performance by providing decision aid algorithms that perform calculations that reduce the computational complexity of search. Most students start searching online with good prior information by first seeking the advice of students with experience buying online. In repeated searches they update the list of sites to search.

We conclude with a brief discussion of the latest in decision aid algorithms improving consumer performance.

2 Experiments

We performed a series of experiments designed to test subjects' performances in solving problems associated with repeated price search. These experiments included

Bayesian multiperiod optimization experiments to test whether students are capable of devising a strategy to optimally learn which store has the lowest relative prices. As these optimization problems are often intractable, Norman and Shimer (1994), we obtained a computationally tractable experiment by using discrete distributions and only three alternatives. The subject needs to buy a textbook each semester and has three choices each period:

1. Travel to store A and buy from store A
2. Travel to store B and buy from store B
3. Travel to both stores A and B, and buy from the cheaper store

The Bayesian question is how many times should the subject check prices at both stores in order to learn which store is cheaper and improve future performance. In the first four experiments the choice is simplified to "Check prices at both stores: Yes or No".

In the paper we shall present an overview of the experiments. In the four one period experiments, subjects were presented with travel cost and relative price information to solve the problems presented in the following display:

Anticipated Price Differences

Stores	Anticipated Price Difference	Check prices at both stores
A and B	\$5	Yes ◯ No ◯
C and D	\$10	Yes ◯ No ◯
E and F	\$15	Yes ◯ No ◯
G and H	\$20	Yes ◯ No ◯
I and J	\$25	Yes ◯ No ◯

In the four one period problems, Anticipated Price Difference, APD, means by how many dollars you anticipate that one store will be cheaper than the other. What

varies in the four problems is the information provided to the subjects about the travel costs and how much they know about the relative prices of the two stores. The subject is informed the cost, $C1$, to check the price at one store and buy from that store and the expected cost, $C2$, to check prices at both stores and buy from the cheaper. In the first two problems, to be labeled 1PnoI 1 and 2, the subject has no information concerning which store is cheaper. In problems three and four, to be labeled as 1PperI 1 and 2, the subject is given a prior probability, expressed as a relative frequency, that the store on the left is cheaper. In the four experiments the anticipated price differences are listed above and the variation in travel cost and knowledge about relatives prices are summarized in the following table:

Table 1
One-period Problem Summary

Problem	$C1$:Cost - Check one	$C2$: Cost - Check both	Probability left store cheaper
1PnoI 1	\$3	\$7	No Info
1PnoI 2	\$5	\$12	No Info
1PperI 1	\$3	\$7	0.60
1PperI 2	\$3	\$7	0.77

After completing 1PnoI 1 and 2 subjects were shown the decisions they made and asked to write a description of their problem solving strategy for these two experiments. The same is the case after 1PperI 1 and 2.

Next subjects solved four 2 period Bayesian optimizations problems that will be labeled 2P 1-4. The subjects were informed about the travel costs, relative prices of the two stores, and were presented the problem to solve in the following display:

Anticipated Price Difference = y_i

	Semester 1	
Check just one store ◯		Check both stores ◯
	Semester 2	
(blank textbox 1) ◯	(blank textbox 2) ◯	(blank textbox 3) ◯

Subject choice in Semester 1 defines the blank HTML textboxes in Semester 2:

Blank textbox is replaced depending on which ◯ is checked in Semester 1

Blank	Semester 1 check one	Semester 1 check both
1	Check just one store	Buy from cheaper store semester 1
2	Check both stores	Buy from more expensive store semester 1
3	DO NOT USE	Check both stores

The one variable that varies in the two-period problems is APD, the value of y_i listed above. The values for the four problems are listed in the table below:

Table 2
Two-period Problem: Values of y_i in table above

Problem	2P 1	2P 2	2P 3	2P 4
APD	\$5	\$15	\$45	\$65

The variables that are the same for the four problems are the travel costs and the information provided about the relative prices of the two stores. The travel cost, $C1$, to check prices at one store and buy from that store is \$6 and the expected travel cost, $C2$, to check prices at both stores and buy from the cheapest is \$14. The subjects are informed that the probability that one store is cheaper is 0.9 (expressed as a relative frequency); but, you have NO information as to which store is cheaper prior to your first semester decision. If you check prices at both stores the first semester, then you

will have one observation which store is cheaper for your second semester decision. After completing 2P 1-4 subjects were shown the decisions they made and asked to write a description of their problem solving strategy for these four experiments.

There were two 49 member subject groups, EcoStat and NoStat where:

1. EcoStat: Economic majors who had completed the undergraduate economic statistics course, which includes a section on Bayes theorem.

2. NoStat: Students majoring in Liberal Arts (except Economics), Communications, Fine Arts, or Education who had not taken any university course in statistics. They also must not have taken more than 3 hours of economics or 6 hours of mathematics.

Subjects gave us permission to verify these requirements and we did. We provided each subject in both groups with a calculator and a sheet of scratch paper to eliminate as many arithmetic errors as possible .

The incentives for the experiment were: Assume you are being paid to advise 100 freshmen about buying a certain textbook. If your recommendations are better in the sense of lower costs on average, you earn more money. The maximum possible earnings is $21

1. You will receive a flat fee of $6 for coming to the experiment.

2. There are 34 questions. You will receive (your score)/(perfect score) $\times$ $15.

The reader, who is interested in the details of the experiments, should use Firefox to go to http://www.eco.utexas.edu/Homepages/Faculty/Norman/00Julia/ to perform the experiments.

3 Results: Experiment

First let us compare the mean performance of the two groups. m_{NS} denotes the mean performance of the 49 NoStat subjects. m_{ES} is the mean performance of the 49 EcoStat subjects. Ran is the expected performance based on random selection. Opt is the performance based on optimal selection in price savings. The data and one tail t tests of the means are presented below. The $m_{NS} < m_{ES}$ test was performed assuming unequal variances.

Table 3
Mean Performance

Ran	m_{NS}	m_{ES}	Op
76	91.99	95.69	100

Table 4
t Tests of Differences in Mean Performance

Test	Ran< m_{NS}	Ran< m_{ES}	$m_{NS} < m_{ES}$	m_{NS} <Opt	m_{ES} <Opt
Sig	<0.001	<0.001	<0.001	<0.001	<0.001

We have three groups of problems, 1PnoI 1&2, 1PperI 1&2, and 2P 1-4. If we consider the performance on each of the groups separately, we get the same relative performance results with a significance of less than 0.025. In all cases, mean subject performance is closer to optimal performance than random performance.

Now let us consider the performance of the strategies of the two groups in the one period problems. Because all subjects had a calculator and scratch paper, arithmetic errors were not considered an important factor. All these problems were designed with a shift point, such that for all anticipated price differences less than the shift point, the correct choice was to only check prices at one store, and for all anticipated price differences greater or equal to the shift point, the correct choice was to check prices at both stores. The shift points for the one period problems, each of which had anticipated price differences of \$5, \$10, ... ,\$25, are:

Table 5

Shift Points for one period problems

Page	1PnoI 1	1PnoI 2	1PperI 1	1PperI 2
Shift Point	\$10	\$15	\$15	\$20

The subjects wrote a description of their strategy to solve the one-period problems. Very few subjects gave a succinct formula for their strategy. In many cases

they described the strategy verbally or used an example. The correct rule for the first two problems, 1PnoI 1&2 is:

if $1/2APD > C2 - C1$, check both buy cheaper, else check one and buy there.

Where APD is the anticipated price difference, $C2$ is the expected cost of checking prices at both stores and buying from the cheaper, and $C1$ is the cost of checking the price at one store and buying there. Two members of the EcoStat group and one member of the NoStat group wrote this rule and executed it correctly. The most common strategy of the two groups was:

if $APD > C2$, check both buy cheaper, else check one and buy there.

Twenty members of the EcoStat group and ten members of the NoStat group wrote this rule and executed it correctly. This rule gives the correct response for the anticipated price differences used in the first two problems.

The correct rule for the second two problems, 1PperI 1&2 is:

$(1 - P)APD > C2 - C1$ check both buy cheaper, else check one and buy there.

where P is the probability that the first store is cheaper. Nine members of the EcoStat group and one member of the NoStat group wrote this strategy and correctly executed it. Twenty members of the EcoStat group and thirty three members of the NoStat group wrote they used an intuitive approach to solve the second set of two problems.

The greater the absolute difference between the anticipated price difference and the shift point the greater the absolute difference in value between checking one store and checking both stores. We hypothesize that the greater the absolute difference between these two choices, the greater the likelihood subject's strategies would select

the correct choice as postulated in the following regression:

$$c_n = \alpha + \beta D_n + \delta \Delta_n + \epsilon_n \tag{1}$$

where c_n is the number correct, α, β , and δ are constants, D_n is a dummy variable which = 0 for the EcoStat group and 1 for the NoStat group, Δ_n is the difference in performance, and ϵ_n is the error term that is assumed to be independent and distributed $N(0, \sigma_n^2)$. We tested the hypothesis of normal errors with the Shapiro-Wilf W, Shapiro-Francia W, and the Skewness/Kutosis tests. All three do not reject the hypothesis of normal errors with a significance level of 5%. We tested the hypothesis of homoskedasticity with the Breusch-Pagan (1979)/ Cook-Weisberg test and rejected this hypothesis with a significance level of 5%.

The results using White's robust regression that corrects for Heteroskedasticity are:

Table 6
Regression 2: Number correct
Number of obs = 40, F(2,37) = 18.39, and Prob > F < 0.0001

Var	Coef	Std Err	t val	P > |t|
δ	1.96	0.33	5.90	<0.001
β	-4.5	1.51	-2.98	.005
α	36.23	1.31	27.59	<0.001

As can be seen, all three coefficients are significant. The larger the gap in performance between the two choices, the better the performance of the subjects' formula and intuitive heuristics. On average, the EcoStat group has 4.5 more correct responses than the NoStat group.

Now let us consider the 2 semester problems for which 3 members of the EcoStat group and 2 members of the NoStat group got all four pages correct.. The rule for

the first semester is:

if $1/2APD + ([(.9)(.9) + (.1)(.1)]APD - 1/2APD) = 0.82APD > C2 - C1$ check both buy cheaper, else check one and buy there.

The shift point for this rule is 9.76 and the rule for the second semester is:

if $0.18APD > C2 - C1$, check both, buy cheaper, else check one and buy there.

The shift point for this rule is 44.44. No subject wrote the correct rule for either problem.

The decision that is revealing is the second semester decision for a price difference of \$45 and \$65. Let us consider the behavior of the 46 EcoStat subjects and 40 NoStat subject that correctly choose to check prices at both stores in the first period. The breakdown of their behavior in the second period is shown in the following table:

Table 7

2nd semester decision for APD of \$45 and \$65

Group	1 and 1	2 and 1	1 and 2	2 and 2
EcoStat	25	1	4	16
NoStat	20	1	1	18

where for 1 and 1, ..., and 2 and 2 the first number is the number of stores checked in the \$45 case and the second number is the number of stores checked in the \$65 case.

The behavior of the various groups is reflected in their written strategies. The 25 EcoStat subjects and the 20 NoStat subjects that chose 1 and 1, either explicitly in their responses or implicitly in their actions, assumed that if they checked prices at both stores in the first period, the store that they found had with the cheaper price would have the cheaper price in the second period with a 90% probability. One EcoStat subject even calculated that the APD would have to be \$80 to warrant

checking both prices in the second period.

Of the 16 EcoStat and 18 NoStat subjects that chose 2 and 2, the most common strategy of these subjects was the heuristic that the greater the APD relative to $C2$, the greater the incentive to check both. One example is, "As the price difference increases, the risk of losing money increases, yet a 90% probability makes it more difficult to decide whether to check both stores. But as the difference goes farther and farther away from \$14 dollars, it becomes more and more convenient to check both stores." Only two EcoStat subjects and one NoStat subject clearly indicated that with only one observation, it was not possible to know with certainly which store was the cheaper 90% of the time.

In conclusion on average subjects performed statistically better than random selection and statistically worse than optimal selection. The subjects with economic statistics had better performance, but many of this group did not understand Bayes theorem, a topic in their statistics course. The subjects in this experiment were less Bayesian than those of El-Gamal and Grether (1995).

We include some results from one of our prior experiments that had 4 periods. For this experiment the subjects for this experiment were 25 students from an author's freshman economics class. We offered a flat fee of \$10 for participating and as much as \$25 more for answering questions correctly. In this experiment we were interested in whether subjects could devise an optimal strategy and paid them if they could.

The parameters and the results for the earlier experiment are shown in the table below:

Table 8: Parameters and Results

	Problem 1	Problem 2	Problem 3	Problem 4
Periods	2	4	4	4
Information	NoP=80	NoP=80	NoP=80	NoP=80
Travel Costs	(5,10)	(5,10)	(5,10)	(5,10)
Anticipated Price Difference	$30	$10	$20	$15
Optimal # to check both	2	1	3	2.32
No. Subjects Correct	6	10	3	2
Avg Checks	1.4	0.88	1.52	1.48
No. Skips	1	7	4	5

The experiment can be viewed at: http://www.eco.utexas.edu/Homepages/Faculty/Norman/00Ashley/ This experiment has two important results. For all three problems the average number of checks of prices at both stores was less than the optimal number of checks and this difference is significant for an α of 0.05 for Problems 1, 3 and 4. Also, a subject should check prices at both stores at the beginning with no skips. The row labeled No. Skips indicates the number of times subjects skipped before checking prices at both stores.

From our experiments we conclude that consumers lack the knowledge to compute an optimal strategy in repeated price searches. Can consumers achieve good performance with heuristic computations?

4 Buying Textbooks Online

To determine repeated price search performance using heuristics, we investigated student behavior in buying textbooks online. The data for this section comes from three student surveys of online textbook buying behavior and from checking the prices of economics textbooks online. We had 107 students fill in a four-page questionnaire and 51 students fill in a later one-page questionnaire; 34 students filled in both surveys.

These students were either attending a meeting of the Texas Economics Association or were enrolled in an upper division economics class. Students were paid $1 per page for their time taking the survey. We also recorded online prices for 23 economics textbooks for 19 days between 28 Dec 07 and 19 Jan 08, collecting 437 data points to determine the lowest prices in the market.

Students at UT buy textbooks each semester. The professor usually defines exactly which books are needed for the class, and students can purchase them from the UT Co-op Bookstore online or at UT Co-op stores near campus. They have the choice of buying a new U.S. edition at the specified price or a used U.S. edition at 75% of the list price regardless of the condition of the used book. Since many students add or drop classes, the UT Co-op Bookstore offers a 12^{th} class day return policy. If students keep the book past the 12^{th} class day, they can sell it back to the Co-op at the end of the semester for half of its current price, regardless of whether the copy was purchased new or used and assuming a professor has requested the book for the next semester. Students buying textbooks at the UT Co-op Bookstore pay 8.25% sales tax, but at the end of the academic year, they have the opportunity to receive a 10% rebate towards future Co-op purchases.

Students can save substantially by buying books online. U.S. editions are frequently cheaper online and for popular textbooks there are less expensive soft-cover foreign editions printed in color on quality paper, and much less expensive soft-cover foreign editions printed in black and white on newspaper quality paper. Also, the price of used textbooks is determined by supply and demand considerations based on the quality of the used book. But, students buying online face a risk that the book

will be delivered late, not delivered, or delivered in a condition different than listed.

As was the case of consumers buying books, CDs, or airline travel services, students buying textbooks online checked few sites. In the one-page survey, online textbook buyers were asked: "How many sites did you check before you made your final textbook purchases last semester?" The average of the 51 economic majors was 3.2 sites. To determine what performance they can achieve in checking few sites we must consider market organization, and how students generate and update their search strategy.

4.1 Market Organization

Most of the online sites that students use to purchase textbooks are what we call "marketplace websites" that list third-party sellers, who describe their offering and set a price. These third party sellers can be students, bookstores, or even other marketplace websites. Unfortunately, there is a risk that the third-party seller will not ship the book on time or will fail to accurately describe the product. To combat this problem, marketplaces provide a rating system of sellers based on comments from previous buyers, but these rating systems vary among marketplace sites and are frequently not comparable. Amazon.com Marketplace, Half.com, BookByte.com, and AbeBooks.com are examples of this genre. Meta-search sites such as PriceGrabber.com, CampusBooks.com, Bigwords.com, and Froogle.com search a variety of mid to large sized sellers to provide a list of vendors ordered by price. Meta-search sites specializing in textbooks, such as CampusBooks.com, search much smaller sellers than general meta-search sites, such as PriceGrabber.com.

Now let us consider the prices of economics textbooks online. We recorded the lowest online market prices for 23 of the undergraduate economics course textbooks for 19 days between between 28 December 2007 and 19 January 2008. We considered three editions: U.S., international color, and international black and white. We also considered two levels of risk: cheapest price with no concern for the reliability rating of the seller and cheapest price from a seller with a 95+ rating with at least 30 transactions. For those sites that used a different rating system, we used as close an approximation as possible. For the U.S. books, we also recorded three quality levels of textbooks: (1) new U.S. edition; (2) good quality U.S. edition with no missing pages, highlighting, or writing; and (3) acceptable used book. For the international editions, only prices for new textbooks were recorded.

In order to determine what sites to check, we started with the meta-search sites. Of these, we found CampusBooks.com and directtextbook.com to be the most useful. From these search engines, we determined which sites would be most useful to check on a daily basis. We checked A1.com, Abebooks.com, Alibris.com, Amazon.com, BN.com, Biblio.com, eBay.com, Express.eBay.com, Half.com, Textbooks.com, Textbooksnow.com, TextbooksRus.com, TextbooksX.com, and Valorebooks.com. We consider the search comprehensive because smaller sellers, who have their own websites, frequently list textbooks at the large marketplaces such as amazon.com and half.com.

In the table below, we show the frequency at which sellers had the lowest price in each of the three categories and the two risk levels for U.S. published textbooks. Sellers who had the lowest price in less than 5% of the surveys were combined into the "Other" category.

Table 9
Cheapest sites in price survey: % of 437 data points

Site	New	New R95	Good	Good R95	Fair	Fair R95
Half.com	28	48	30	49	28	49
Amazon.com	35	31	34	30	21	23
AbeBooks.com	5	5	9	7	12	12
Textbooksnow.com	4	5	2	0	9	8
Valore.com	6	0	6	7	6	1
Other	22	11	19	7	24	7

If students buying economics textbooks only checked prices at Half.com and Amazon.com and then bought from the cheaper, they would find the lowest price at least 49% of the time. However, the real issue is how close students are to the optimal strategy; if they miss the cheapest book half the time but only pay a cent extra, the difference is negligible. We can estimate how good a strategy is by comparing the students' performances with checking all sites, just Half.com, just Amazon.com, or both Amazon.com and Half.com for the lowest prices. This is shown in the following table where performance is measured relative to the cheapest price set to 1.

Table 10
Performance of Amazon.com and Half.com Strategies

Strategy	New	New 95	Good	Good 95	Fair	Fair 95
Both	1.05	1.03	1.06	1.02	1.08	1.02
Amazon.com	1.12	1.14	1.13	1.12	1.14	1.12
Half.com	1.12	1.06	1.12	1.06	1.13	1.05

Assuming the students are searching for "Fair" quality textbooks, the table shows that checking both Amazon.com and Half.com would result in a strategy that is at most 8% higher than the lowest price we found. In the cases where students are searching for new textbooks and use a 95+ rating to reduce risk, the increase is no greater than 3%. We then compared these prices with the listed UT Co-op Bookstore

prices. In an earlier version of the paper we showed that there is a slight upward trend in price data. Therefore, we show this comparison for three different days in the table below:

Table 11
Cheapest Prices relative to UT Co-op Bookstore (Percent)

Day	New	New 95	Good	Good 95	Fair	Fair 95
28 Dec	58	64	66	69	65	68
6 Jan	61	66	68	77	66	72
19 Jan	60	67	73	83	72	78

We assume that students buying online would start their search by checking the ISBN numbers of their course textbooks and recording the listed prices. These prices would be lower than the online prices 1%, 2%, and 6% of the time in the cases of "New 95," "Fair," and "Fair 95" respectively. However, the buyer could not tell whether the UT Co-op Bookstore actually had the textbook in stock without a phone call or actually visiting the store, an additional labor cost. By the time the semester has started, the UT Co-op Bookstore frequently has run out of some textbooks.

We also checked prices for new international black and white and new international color at two risk levels each. The low cost sites are shown below:

Table 12

Cheapest sites for new international editions (Percent)

Site	NIB	NIB R95	NIC	NIC R95
Abe.com	53	84	28	33
eBay .com	16	14	30	42
TextbooksRUS.com	9	1	21	7
a1.com	22	0	7	0
Valore.com	0	0	4	13
Other	0	0	9	4

Again, a strategy just to check prices at Abe.com and eBay.com results in the lowest price 69%, 98%, 58% and 75% of the time for the four categories. In the case of international editions, we did not collect data in order to determine how close the top two would be to optimal.

Given the organization of the online textbook market, students only have to check prices at a small number of sites in order to achieve good performance. Marketplace sites such as Amazon can list several hundred third party sellers of popular textbooks. Amazon encourages competition among these sellers by providing the buyer with a list ordered from lowest to highest price. This list also reduces the computational complexity of finding the lowest price from linear to constant: Instead of making $n-1$ comparisons to find the lowest price in a list of n items, the buyer selects the first item. Buyers frequently want to make a price decision in which they consider the tradeoff between higher seller risk and lower price. With a list ordered by increasing price implementing such a heuristic is straightforward, but not so with an unordered list. Humans are capable of implementing a linear algorithm for sorting a small number of items, see Norman et al (2003), but the number of alternatives and price data would make the implementation of such an algorithm difficult.

Using a meta-search site a consumer does not have to consider solving the Bayesian optimization problem for the sites searched by the meta-search site. Because these sites do not search continuously, a student can go to a site only to find the low cost book displayed by the meta-search site is no longer available. Nevertheless, they do provide useful data as to which sites are worth checking.

4.2 Search Strategy

Now we can discuss how students obtain knowledge about their alternatives for purchasing textbooks. Of the 107 students who filled in the four-page questionnaire, we excluded 11 for indicating a major other than economics and 4 for too much missing data. When asked for their information sources, the students responded as shown in the following table:

Table 13
Data sources for students using many sellers (n=92)

Source	Number	%
Friends/Relatives	73	78
Professors	17	18
Search Engines	54	58
Advertisements	23	24
Other	4	4

In our survey, when asked "From how many people did you obtain advice?" the average response of those that sought advice was 3.5 people. Is this enough to obtain good advice?

Let us consider the sites students would recommend. On page three of the survey participants were given a list of sites and asked which sites (1) they would recommend freshmen check textbook prices, (2) they had checked prices, (3) they had bought textbooks, and (4) they were previously unaware. Their responses are displayed below:

Table 14
Questions about sites (n=92) Meta-Search Sites

Source	Recommended this site	Checked this site	Bought from site	Unaware of site
PriceGrabber.com	5	25	1	57
Froogle.com	7	21	1	62
BigWords.com	2	8	3	78
CampusBooks.com	14	36	10	48

Table 15
Questions about sites (n=92) Marketplace Sites

Source	Recommended	Checked	Bought	Unaware
1: AbeBooks.com	28	40	26	48
2: Alibris.com	7	19	10	66
3: Amazon.com	76	85	75	0
4: B & N Online	15	67	12	8
5: BookByte.com	5	15	7	63
6: eBay.com	46	74	43	1
7: Half.com	62	72	63	8
8: Texbooks.com	8	34	10	44

Table 16
Questions about sites (n=92) UT Co-op and campus stores

Source	Recommended	Checked	Bought	Unaware
1: UT Co-op Online	10	73	32	8
2: Half-Price Books	22	57	28	13
3: UT Co-op Bookstore	13	76	58	0

As can be seen from the tables above, students most frequently recommend and buy from Amazon.com. Half.com is second in these two categories. All but one of the students recommended at least one of these two sites, and 63 out of the 92 recommended both. Also, 68% of the 58 students who bought international edition textbooks recommend at least one of the top sites for these textbooks. Therefore, students do not have to talk to many previous buyers to obtain good information

concerning relative prices, and this limits their need to search a large number of sites. Also, 57% of these students used at least one of the meta-search sites, which eliminates the need to check prices at listed sites without low prices.

It is important to question how students modified their buying strategy to see if they improve their performance over time. The data shows students have searched for textbooks online from multiple sources an average of 5.01 times with a range from 1 to 12 times. Let us consider using regression analysis how their behavior changed with the number of times they search for textbooks online. We postulated the following regressions with the assumption that β_2, β_4, and β_5 would be positive and that β_3 would be negative:

$$ch_n = \alpha_2 + \beta_2 sem_n + \epsilon_{2n} \tag{2}$$

$$unk_n = \alpha_3 + \beta_3 sem_n + \epsilon_{3n} \tag{3}$$

$$buy_n = \alpha_4 + \beta_4 sem_n + \epsilon_{4n} \tag{4}$$

$$rec_n = \alpha_5 + \beta_5 sem_n + \epsilon_{5n} \tag{5}$$

where sem_n is the number of semesters and summer sessions the student bought textbooks online, ch_n is the number of sites the students checked over all searches, buy_n is the number of sites from which the student bought over all searches, rec_n is the number of sites the student recommended from the searches, and unk_n is the number of unknown sites after completing the searches. We tested the hypothesis of normal errors for these four regressions with the Shapiro-Wilf W, Shapiro-Francia W, and the Skewness/Kutosis tests. All three test rejected the hypothesis of normal errors with a significance level of 5% for the fourth regression above, but all three

tests did not reject the normal hypothesis for any of the other regressions. We tested all four regressions for the hypothesis of homoskedasticity with the Breusch-Pagan/ Cook-Weisberg test. The hypothesis of homoskedasticity was not rejected with a significance level of 5%. The F test for the regressions was significant at < 0.01 for regessions (2) - (4) and significant at < 0.103 for the regression (5). The results for the β coefficients are displayed below:

Table 17
Regression 2: Number Checked

Equation	Coef	Value	Std Err	t val	P > |t|
(2) Number Checked	β_2	0.30	0.10	2.87	.005
(3) Unknown	β_3	-0.42	0.11	-3.8	<0.001
(4) Number Bought	β_4	0.16	0.07	2.38	.02
(5) Number Recommended	β_5	0.13	0.08	1.65	0.102

The signs of β_2, β_4, and β_5 are positive with decreasing significance. These coefficients have small values indicating that these variables change slowly with an increasing number of searches. The sign of β_3 is significantly negative and larger in absolute value than the coefficient β_2. The fact that $\beta_2 - \beta_5$ have small values demonstrates the fact that student start with a good search strategy and make small adjustments with subsequent searches.

Students add sites, but they also drop sites. The forty students who filled in both the one-page and four-page questionnaires on average checked prices at 6.6 sites during all their searches and 3.3 sites the last time they checked prices. One student checked the same number in both measures and the rest checked more sites during all their searches. The difference is significant for a significance level of $1.0 \times 10^{-8}\%$. From our questionnaires we found that students would drop sites from future consideration if they had no success at a site. Another reason students drop sites is to reduce

future risk of late delivery or of no delivery at all. Of the 92 students, 54 had a book delivered late, and 2 had a book that was never delivered. Of these students, 12 dropped the seller from future consideration. In addition, students limit their search to reduce risk. When asked, 47% of the one-page survey students checked "I prefer to check prices at sites with a large number of buyers and sellers such as Amazon.com or Half.com because they have a well-defined rating system that I use to reduce risk." Also, 47% of these students indicated that they were not looking for new sites because it was not worth the effort or risk.

On page two of the survey, subjects were asked, "For those years you bought books at sites other than the UT Co-op or UT Co-op Online, please estimate to the nearest 10% how much you saved relative to the UT Co-op price (new or used as appropriate)?" Subjects were asked to fill in their percent savings in boxes for "First year," "Second year," "Third year," and "Fourth year." The mean of the 77 observations for students who had bought textbooks online for at least two years was 29.9% for the first year and 34.5% for the second year. The difference is statistically significant for a one-tail test with a significance level of 0.1%, indicating that students believe their performance improves with experience.

Now let us consider how student strategies achieve performance without much calculation. In obtaining advice from experienced online textbook buyers, the knowledge of which sites to search is passed from one generation of textbook buyers to the next. There is no need to be able to compute Bayesian optimization strategies and this is amplified by meta-search sites.

5 Conclusion

The Internet market organization has marketplace sites like Amazon.com and meta-search sites like PriceGrabber.com for many products so consumers are able to obtain good performance in price search for many different types of products checking just a few sites. The marketplace on the Internet is undergoing continual change. Business to consumer sales are growing, and the use of the Internet to do background research about prices and products is growing even faster. The growth of price searching online is indicated by the fact that Experian bought PriceGrabber.com in 2005 for $485 million, see top news December 15, 2005 at Socialtech.com.

Price search is in flux because of new technology such as price search applications such as ShopSavvy and RedLaser on the iPhone and other smart cell phones. The consumer takes a picture of a barcode on a product in a store and the app gives the consumer prices from competing sellers, both online and in local stores. On the Friday after Thanksgiving 612,488 consumers used ShopSavvy to find the best price, see "ShopSavvy iPhone App Black Friday Numbers" posted 2 Dec 2008 at geardiary.com. In addition to the efficiencies of an ordered list discussed at the end of section 4.1, these procedures can be initiated any time a consumer encounters a product of interest in a store.

References

1. Mahnoud, El-Gamal and David Grether, 1995, Are People Bayesian? Uncovering Behavioral Strategies, *Journal of the American Statistical Association,* 90(432),, 1137-1145

2. Breusch, T.S. and A. R. Pagan, 1979 Simple test for heteroscedasticity and random coefficient variation. Econometrica 47 (5): 12871294

3. Johnson, E., W. Moe, P. Fader, S Bellman, and G. Lohse, 2004, ON the Depth and Dynamics of Online Search Behavior, Management Science, Vol. 50. No. 3, pp 299-308

4. Kogut, C., 1990, Consumer Search Theory and sunk Costs, Journal of Economic Behavior and Organization 14, 381-392

McMillan, J. and M. Rothschild, M.,1994 . Search Theory, In: Aumann R., Hart S. (Eds.) Handbook of Game Theory with Economic Applications, vol. 2,, Chapter 27 pp. 905927 North Holland: Amsterdam

5. Norman, Alfred. and David Shimer. "Risk, Uncertainty and Complexity", *Journal of Economic Dynamics and Control*, 18, 1994, 231-249.

6. Norman, A., A. Ahmed, J. Chou, K. Fortson, C. Kurz, H. Lee, L. Linden, K. Meythaler, R. Rando, K. Sheppard, N. Tantzen, I. White and M. Ziegler, 2003, "An Ordering Experiment", *Journal of Economic Behavior and Organization*, Vol 50 249-262.

6, Sonnemans, J., 1998, Strategies of Search, 1998, Journal of Economic Behavior and Organization 35, 309-332

7. White, Halbert. "A Heteroskedasticity-Consistent Covariance Matrix estimator and a Direct Test for Heteroskedasticity", *Econometrica*, 48(4), 1980, 817-838