Decision Heuristics and Repeated Price Search

A. Norman, 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

June 28, 2009

Abstract

We investigate student textbook search using experiments, surveys, and data analysis. We created one- and two-period search experiments in order to study subjects' heuristics. This experiment was performed with two groups of 49 students, of which one had taken a course in statistics. Subject performance was better than random and less than optimal. Subjects with statistics course performed better than those without, but many subjects in both groups made mistakes in Bayesian reasoning. We surveyed seniors to characterize campus bookstore buyers versus online buyers. In the marketplace, students talk to experienced peers to develop buying strategies. We recorded online prices for 24 days to analyze actual student strategies. Students can achieve good performance by checking two websites listing large numbers of sellers ordered by price and quality.

Send correspondence to:
Alfred Lorn Norman
Department of Economics
The University of Texas at Austin
Austin, TX USA 78712
E-Mail: norman@eco.utexas.edu
Phone: 512-346-4253

1 Introduction

We consider how consumers solve repeated price searches using the methodology of experiments, surveys, data collection and analysis. The standard one-period price search is modeled as random drawing, but this is not a good model for a repeated price search. Consumers buy many products at frequent intervals such as food, clothes, and in the case of college students, textbooks. In repeated price search a consumer learns which stores and sites sell which products and the relative prices of these sellers. For example, consumers learn that prices at a discount store, such as Wal-Mart, are generally lower than a department store, such as Saks Fifth Avenue. As a consumer learns the relative prices of sellers, the consumer uses this information to improve the efficiency of the price search.

In this paper we present the fifth version of our experiment. Because in our previous experiments subjects did not solve the Bayesian optimization problem, we decided to explore their knowledge more deeply by creating a simpler experiment. In order to remove arithmetic errors as a performance factor, all subjects were given a calculator and a piece of scratch paper. This experiment had five problems that were designed to test subjects' intuitive decision heuristics and see how well they understood the problems. The optimal solution of the first two problems had a simple deterministic rule, the optimal solution of the next two had a simple expected value rule, and the final rule required a Bayesian update of observed data. There were two groups of 49 students each: (1) economics majors who had completed the course in economic statistics, (2) students majoring in Liberal Arts (except Economics), College of Communications, Fine

Arts, or Education who had not taken a university course in statistics, had no more than 3 hours of economics and no more than 6 hours of mathematics.

The performance of both groups was statistically better than random choice and statistically worse than optimal. The performance of the statistics group was statistically superior to that of the non-statistics group. In the experiment subjects answered question testing their knowledge of the problems. Using regression analysis we determined that performance on this test was a significant factor in explaining performance in the experiment. Performance in the one period problems can also be explained by a dummy variable identifying the statistics course group and a variable measuring the absolute difference between the two choices. In the two-period problem, many subjects in the both groups demonstrated a lack of knowledge of Bayes theorem.

Another approach to learning the relative prices of sellers is to seek information from experienced shoppers. In Section 4, we consider the textbook market at UT. We use four surveys to characterize the UT Co-op buyers and online multisite buyers. The former are willing to pay higher prices in return for the convenience of the Co-op; others search many stores and Web sites saving about 40% relative to the Co-op prices over time, but with a risk of receiving books late or not delivered and with overstated quality. Most students initiating buying online seek the advice of students with experience buying online. We also checked the prices for economic textbooks for all undergraduate classes online at multiple websites for a period of 21 days looking for a new, good used, and acceptable used textbook for two risk factors. Because many of these sites are

marketplaces listing numerous sellers, a students only has to check a few sites to achieve good performance for different risk levels and obtain the advice from a small number of experienced buyers to identify these sites.

Section 6 we conclude that market organization is the most important factor leading to performance. This is the fifth paper in a series developing a procedural consumer. The earlier papers are Norman et al (2001, 2003, 2004, 2008).

2 Experiments

We performed a series of experiments designed to test subjects' performances in solving problems associated with repeated price search. These experiments included a Bayesian multiperiod optimization experiment 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 (1994), we obtained a computational 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.

This is the fifth experiment in our series. We started with a time horizon of 8 semesters and with each improvement of the experiment we shorted the time horizon. Because subjects were not able to devise an optimal strategy for a potentially tractable two period Bayesian optimization problem requiring five arithmetic operations, we decided to probe more deeply into the actual heuristics they employ in one and two period problems. The third and fourth experiments led to improved instructions and design. To view the fifth experiment use Firefox and go to: http://www.eco.utexas.edu/Homepages/Faculty/Norman/00Julia.

On page 1 of the experiment the subject was given general instructions. On pages 2 and 3 we present the subject with two 1 period problems where the subject has no information concerning the cheaper store. The problem description on page 2 is:

> **Information:** In this case one of the two listed stores is cheaper than the other most of the time. But, as you have had no previous experience with these two stores, you have NO information as to which store is cheaper.
> **Travel Costs:** If you check the price at only one store and buy from that store, it costs you \$3. If you check the price at both stores and buy from the cheapest, your expected cost is \$7. The expected cost of \$7 would be your average cost that includes the fact that sometimes you would have to return to the first store.
> **Anticipated Price Differences:** Now suppose you anticipate that one store will be cheaper than the other by \$X where the values of X are given below. For each price difference indicate whether you would check the price at both stores.

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 ◯

The problem description for page 3 was the same as page 2 except the travel

cost to one store was $5 and the expected travel costs to both stores is $12. The 1 period problems with no information on pages 2 and 3 will be referred to as 1PnoI 1 and 2. On page 4 subjects were provided a summary of their decisions on page 2 and 3 and asked to write a description of their problem solving strategy for these two pages in a textarea.

On pages 5 and 6 we present the subject with two 1 period problems where the subject has perfect information. Page 5 is the same as page 2 except the Information description has been replaced with:

> **Information:** In talking with seniors about the price at the listed stores below, you can assume that if you checked the price at both stores 100 times you would find that 65 times the first listed store (A, C, E, G, and I) would be cheaper and 35 times the second listed store (B, D, F, H, and J) would be cheaper.

On page 6 the problem description was the same as page 5 except the Information description has been replaced with:

> **Information:** In talking with seniors about the price at the listed stores below, you can assume that if you checked the price at both stores 100 times you would find that 77 times the first listed store (A, C, E, G, and I) would be cheaper and 23 times the second listed store (B, D, F, H, and J) would be cheaper.

The 1 period problems with perfect information on pages 5 and 6 will be referred to as 1PperI 1 and 2. On page 7 subjects were provided a summary of their decisions on page 5 and 6 and asked to write a description of their problem solving strategy for these two pages in a textarea.

On pages 8-11 the subject is presented with four 2 period problems. The problem description on page 8 was:

> **Information:** In this case you will make decisions as to checking the price at two stores, A and B for two semesters. If you did price-comparison shopping at the two stores 100 times, you would find one of the two stores was cheaper 90 times out of 100. But, as you have had no previous experience with these two

stores, you have NO information as to which store is cheaper prior to your first semester decision. For your second semester decision you have one observation which store is cheaper if you check prices at both stores the first semester.
Travel Costs: If you check the price at only one store and buy from that store, it costs you $6. If you check the price at both stores and buy from the cheapest, your expected cost is $14. The expected cost of $14 would be your average cost that includes that fact that sometimes you would have to return to the first store.
Anticipated Price Differences: You anticipate that one store will be cheaper than the other by $5.
Two Semester Problem: This is a 2-semester problem. Suppose in the first semester you decide to check prices at both stores in semester one and buy from the cheaper store. You would have one observation as to whether store A or store B is cheaper. Note: In semester 2 use the appropriate row based on what action you took in semester 1. In the tables below Check just one store means go to either store A or store B and buy without checking price at the other store and Check both stores means check price at both and buy from cheaper store.

Anticipated Price Difference = $5

	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 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

Pages 9, 10, and 11 are the same as page 8, except that the Anticipated Price Difference becomes $15, $45, and $65 respectively. The 2 period problems on pages 8-11 will be referred to as 2P 1-4. On page 12 subjects were provided a summary of their decisions on pages 8-11 and asked to write a description of their problem solving strategy for these four pages in a textarea.

The following table summarizes the eight problems:

Table 1: Problem Summary

Problem Name	Travel Cost	Percent A cheaper	Range APC	# Periods
1PnoI 1	3/7	No Info	\$5-\$25	1
1PnoI 2	5/12	No Info	\$5-\$25	1
1PperI 1	3/7	0.60	\$5-\$25	1
1PperI 2	3/7	0.77	\$5-\$25	1
2P 1	6/14	0.90	\$5	2
2P 2	6/14	0.90	\$15	2
2P 3	6/14	0.90	\$45	2
2P 4	6/14	0.90	\$65	2

Where 3/7 means the travel cost to one store is \$3 and the expected travel cost to two stores and buying from the cheaper store is \$7. APC is the anticipated price difference.

On the last page subjects were asked questions testing their knowledge:

Answer questions 1 - 5 below from you experience with the previous 4 problems. There is a correct answer for each and each correct answer will raise your score by one point.
1. The greater the anticipated price difference the more times you should check prices at both stores
True ◯ or False ◯
2. The higher the travel costs to both stores the more times you should check prices at both stores
True ◯ or False ◯
3. If you know for certain the probability is 0.95 that the price at store A is cheaper, then there could be an anticipated price difference that makes checking prices at both stores worth the cost.
True ◯ or False ◯
4. In the two semester problem, if you are going to check prices at both stores once it makes no difference whether you check both prices in the first semester or the second semester
True ◯ or False ◯
5. Given two stores, A and B. If you checked prices at two stores 100 times you would find one of the two stores cheaper 70 times out of 100. Consider two cases: 1) you have no prior knowledge which store is cheaper and you check prices at both stores once and you find that A has lower prices; 2) you have no prior knowledge which store is cheaper and you check prices at both stores twice and you get the same store, A, as having the lower prices twice. You should be more confident in 2) than in 1) that the store that you found to be cheaper, A, is actually cheaper 70 times our of 100
. True ◯ or False ◯

We performed this experiment on two 49 member 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 a 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 much as possible arithmetic errors.

The incentives for the experiment were:

Incentives:
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.

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 with unequal variances.

Table 2: Mean Performance

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

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 factors that explain the subjects performance. The last page of the experiment asked participants T/F questions to gauge their intuition about the problems presented in the experiment. We postulated that the performance of the subjects could be explained by the following regression:

$$S_n = \alpha + \beta Q_n + \epsilon_n \tag{1}$$

where S_n is the score of the n_{th} subject, Q_n is the number questions correct and ϵ_n is the error term. The difference in performance of the two groups raises the issue of heteroscedasticity. The scores of the NoStat group were lower and with higher variance than those of the EcoStat group. The average number of questions right for the EcoStat group was 4.1 out of 5 and the average number of questions right for the NoStat group was 3.8 and the difference is statistically significant with a one tail t test assuming unequal variances with

an α of 0.033. We tested the null hypothesis of homoscedasticity using the Goldfeld-Quandt (1965) test dividing the data into the EcoStat and NoStat groups and the this hypothesis was rejected with an α of 0.01. Consequently we calculated the regression with ordinary OLS and with the White (1980) correction for heteroscedasticity.

Table 3: Regression 1: Total performance
Number of obs = 98, F(1,96) = 7.94, and Prob > F = 0.0059

Var	Coef	Std. Err.	t value	Prob > |t|	Rob SE.	Rob t val	Rob P> |t|
Q_n	1.878	.666	2.82	0.006	.626	3.00	0.003
α	86.35	2.75	31.42	<0.001	2.82	30.66	<0.001

where Rob stands for robust regression with White correction. We see the coefficient on Q_n is highly significant. This confirms that intuitive knowledge about these types of problems leads to better performance.

Now let us consider the performance of the two groups strategies 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, which each had anticipated price differences of \$5, \$10, ... ,\$25, are:

Table 4: 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 first two one-period problems on page 4 and the second two one-period problems on page 8. 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, 1PnoI1&2 is:

if 1/2APC > Tra2, check both buy cheaper, else check one and buy there.

where *APC* is the anticipated price difference and *Tra2* is the expected travel cost to the second store. 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 APC > TraB, check both buy cheaper, else check one and buy there.

where *TraB* is the expected travel cost to both stores. 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, 1PperI1&2 is:

(1-P)APC>Tra2 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 the two choices. We hypothesize that the greater the absolute difference between the two choices, the greater the likelihood subject's strategies would select the correct choice as shown below:

Table 5: Number of subjects with correct answer (n = 49)

Problem (Page)	**1PnoI 1 (2)**					**1PnoI 2 (3)**				
APC	5	10	15	20	25	5	10	15	20	25
EcoStat	36	40	47	48	48	47	33	41	46	46
NoStat	41	24	44	44	44	42	36	31	43	41
Dif	1.5	1	3.5	6	8.5	4.5	2	0.5	3	5.5
Problem (Page)	**1PperI 1 (5)**					**1PperI 1 (5)**				
APC	5	10	15	20	25	5	10	15	20	25
EcoStat	45	33	37	45	45	45	41	30	38	42
NoStat	43	38	22	35	40	44	38	34	24	35
Dif	2.25	0.5	1.25	3	4.75	2.85	1.7	0.55	0.6	1.75

where APC is the anticipated price difference, and Dif is the absolute difference in performance between the two choices.

We postulated the following regression:

$$c_t = \alpha + \beta D_t + \delta \Delta_t = \epsilon_t \tag{2}$$

where c_t is the number correct, α, β , and δ are constants, D_t is a dummy variable, which = 0 for the EcoStat group and 1 for the NoStat group, Δ_t is the difference in performance, and ϵ is the error term. We tested the hypothesis of homoscedasticity with the Goldfeld-Quandt test and rejected this hypothesis with and α of 0.05.

The results using OLs and using the White correction 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|	Robust SD.	Rob t val	Rob P > |t|
dif	1.956	.357	5.48	<0.001	.332	5.90	<0.001
dum	-4.5	1.51	-2.98	.005	1.511	-2.98	0.005
α	36.233	1.46	24.88	<0.001	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 1/2APC + ([(.9)(.9) + (.1)(.1)]APC -1/2APC) = 0.82APC > Tra2 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 0.18APC > Tra2, 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 APC 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 the various groups is reflected in their strategies that they wrote in the textarea. 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% probablity. One EcoStat subject even calculated that the APC 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 APC relative to the TraB 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, you did not know with certainly which store was the chearper store 90% of the time.

In conclusion subject performance was statistically better than random selec-

tion 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).

4 Buying Textbooks Online

The data for this section comes from student surveys of textbook buying behavior and checking the prices of economics textbooks online. We surveyed over two hundred students over the past several years and refined the survey questions over time. We will use the data from the last two surveys of students attending a meeting of the Texas Economics Association and students in an upper division economics class. Students were paid $2 plus $1 a page for their time. There were 66 students who bought from the UT Co-op and 68 who bought online. We also recorded online prices for 23 economics textbooks over a period of 22 days from 28 Dec 07 to 19 Jan 08, collecting 437 data points.

Students at UT buy textbooks each semester. The professor usually defines exactly which materials are needed for the class, but the student still faces a wide number of textbook choices. Popular textbooks are frequently available in U.S. editions, less expensive softcover foreign editions printed in color on quality paper, and much less expensive softcover foreign editions printed in black and white on newspaper quality paper. Though there are some legal issues in selling these foreign editions in the U.S., students can take advantage of the low prices in buying these editions online.

If a student buys from the UT Co-op, they can buy a new U.S. edition at the UT Co-op 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 offers a 12 class day return policy. If she keeps the book, she can sell it back to the Co-op at the end of the semester for half of its new price (regardless of whether the copy she purchased was new or used) assuming a professor has requested the book for the next semester. Students buying textbooks at the UT Co-op pay 8.25% sales tax, but at the end of the academic year, they have the opportunity to receive a 10% rebate towards Co-op purchases.

Students search multiple sites online hoping to save about 40% from the UT Co-op prices, but risk that the book will be delivered late or not at all or not be in the listed condition. Based on the survey, online textbook buyers contribute more of their personal income to textbook purchases as opposed to their Co-op counterparts, 27.1% versus 8.7% respectively. Seventy-eight percent of the online buyers purchase online so they can spend their savings on other needs. Students buy from the UT Co-op for convenience and zero risk of non-delivery. If their parents allow them to buy from the UT Co-op with their credit card, the students lack incentives to shop around. Seventy percent of the UT Co-op buyers buy from the Co-op to receive books immediately and not risk a late delivery.

Most of the online sites that students use to purchase textbooks are what we call marketplace websites. In contrast to a traditional, direct sales site like Amazon.com, marketplace sites list third-party retailers, who describe their offering

and set a price. These third party sellers can be students, bookstores, or even other marketplace websites. Amazon Marketplace, Half.com, BookByte.com, and AbeBooks.com are examples of this genre. The most important characteristic of marketplace sites is their low cost. Unfortunately, there is a risk that the third party seller will not ship the book on time or will fail to accurately describe their product. To combat this problem, marketplaces provide a rating system of sellers based on comments from previous buyers; however, these rating systems vary among marketplace sites and are frequently noncomparable.

Another variety of product search sites are meta-search sites, such as PriceGrabber.com, CampusBooks.com, Bigwords.com, and Froogle.com. These sites search a variety of mid to large sized sellers to provide a list of vendors ordered by price. By using such a site, a consumer can search many marketplaces for their desired product, covering a broader selection of sellers with less effort. These sites are not so widely used, in part because they may be less well known and they suffer from spurious results. For example, sites that say they charge one dollar for a book, provided the consumer participates in arcane point-trading programs or advertising offers. They also do not search continuously: a student can go to a site to find the low cost book indicated by the meta-search site only to find that the book is no longer available.

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: US books, International Color, Interna-

tional Black and White, and two levels of risk: cheapest price with no concern for the reliability rating of the seller and 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 US 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 the most useful. From these search engines, we determined the sites 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 at the large marketplaces such as amazon.com and half.com.

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

Table 8: 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 a student buying an economics textbook only checked prices at Half.com and Amazon.com and bought from the cheaper, they would find the lowest price at least 49% of the time. But the real issue is how close a subject comes to the optimal strategy: if the student misses the cheapest book half the time but only pays a cent extra, their difference is negligible. We can estimate how good a strategy is by comparing the student's performance 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 9: 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 student is searching for a Fair quality textbook, 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 the student is searching for a new textbook and uses a 95 rating to reduce risk, the increase is no greater than 3%. When then compared these prices with the listed UT Co-op prices. In an earlier version of the paper we showed there is a

slight upward trend in price data; therefore, we show this comparison for three difference days in the table below:

Table 10: Cheapest Prices relative to UT Co-op (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 record 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 actually had the textbook in stock without a phone call or actually visiting the store. The UT Co-op supplies frequently run out and this presents an additional cost.

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 11: 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.

Now let us consider student performance based on the survey data. A UT student completing a four year program in 8 semesters and 6 summer sessions could buy textbooks online from multiple sites as many as 14 times. The average number of times a student in the surveys bought books online was 4.9 so most students had time to learn a good strategy. Of the students in the survey, 44% started buyings textbooks online in the first year, 29% in the second year, 22% in the third year, and 4% in the fourth year.

To evaluate their performance consider the table below. 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, (4) they were previously unaware.

Table 12: Questions about sites (n=64)

Source	Recommended this site	Checked this site	Bought from site	Unaware of site
SE1: PriceGrabber.com	3	22	1	30
SE2: Froogle.com	7	21	3	31
SE3: BigWords.com	2	9	3	40
SE4: CampusBooks.com	11	27	7	27
OL1: AbeBooks.com	21	24	16	28
OL2: Alibris.com	5	11	7	38
OL3: Amazon.com	50	51	49	1
OL4: BookByte.com	3	8	5	37
OL5: eBay.com	33	44	29	2
OL6: Half.com	50	49	49	3
OL7: Texbooks.com	8	23	9	24
OL8: Textbooksnow.com	6	32	7	20
OL9: B & N Online	12	45	12	4
OL10: UT Co-op Online	6	39	18	3
PS1: Half-Price Books	18	33	19	3
PS2: UT Co-op Bookstore	11	27	37	0

All of the students bought US textbooks. In terms of recommending Amazon.com and Half.com, 62% recommended both and 95% recommended at least one of the two. When asked to list the cheapest two sites, 32% list both Amazon.com and Half.com and 95% listed at least one. Of the 21 students who bought international editions, 81% recommended at least either eBay.com and AbeBooks.com. Subjects' strategies were based on good knowledge about their alternatives.

Students who buy textbooks online must deal with late or even no delivery. One approach to reduce risk is to use the rating system of sellers provided by the sites. 63% of the students used such a system with the median rating required to consider a purchase 90% and a median of 10 transactions. 67.7% of the students reported late delivery and one student's textbook was never delivered.

Now we can discuss how students obtain knowledge about their alternatives

for purchases textbooks. When asked their information sources, the students responded as shown in the following table:

Table 13: Data sources for students using many sellers (n=68)

Source	Number	%
Friends/Relatives	52	76
Professors	11	16
Search Engines	38	56
Advertisements	17	25
Other	4	6

Because students that have bought textbooks online generally have good knowledge, a student starting to buy textbooks online would only have to seek advice from a few experienced students to develop a good strategy.

5 Conclusion

Kahneman and Tversky (1982) lead a group of decision psychologist with the agenda of showing economics agents do not optimize, but use heuristics that can achieve good performance. The principle factor that leads to performance in textbook buying is market organization in the form of marketplace sites such as Amazon.com can list over 400 sellers in their marketplace and have well established rating systems. A student only has to check Amazon.com and Half.com in order to obtain a good price. To find such sites a new online buyer only has to talk to a few experienced seniors and does not have to accurately solve Bayesian optimization problems in price search.

References

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

2. Goldfeld, Stephen and Richard Quandt. 1965 "Some Texts for Homoscedasticity", *Journal of the American statistical Association* 60(310),539-547 3. Kahneman Daniel, Paul Slovic, and Amos Tversky. 1982. *Judgment under Uncertainty: Heuristics and Biases*, Cambridge, U.K: Cambridge University Press

4. Norman A, A. Ahmed, J. Chou, A. Dalal, K. Fortson, M. Jindal, C. Kurz, H. Lee, K. Payne, R. Rando, K. Sheppard, E. Sublett, and I. White. 2004. "On the Computational Complexity of Consumer Decision Rules", *Computational Economics*, 23(2), 173-192

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

7. Norman, A. (1994), On the Complexity of Linear Quadratic Control, *European Journal of Operations Research*, 73, pp. 319-330.

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