Sequential Consumer Model

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Abstract

Even if the microeconomic consumer maximization model is made discrete, the resulting complexity of optimizing over bundles of goods is not tractable for bounded rational humans. We construct a sequential consumer model based on a sequence of individual item searches and consider the relationship between the discrete sequential model and the discrete bundles model. We consider two aspects of the sequential model. First, we survey undergraduate budgeting. Progress towards optimization proceeds by an incremental adjustment process. Students' self-ratings on budget performance are related to how frequently they monitor their checking account. In a sequential model, we can consider how close to optimal is a single consumption decision conditioned on a prior correct budget appropriation. We perform an experiment with pens to show that high search costs and large numbers of alternatives imply that pen decisions are suboptimal and we provide a measure of how far from optimal.

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1 Introduction

The computational complexity of the traditional microeconomic consumer maximization model is transfinite except in special cases. Even if the model is made discrete, the computational complexity is exponential in the number of goods in each category, Norman et al (2001). The computational difficulty arises because the number of alternative bundles that must be considered is the number of goods in each category raised to a power equal to the number of categories. To reduce the computational complexity, consumers shop for their market baskets item-by-item.

In section 2, we discuss these issues and create a sequential model for consumer behavior. We first provide an intuitive example of why consumers shop for purchases item-by-item and not by bundles. We then review the computational problems of a discrete version of the two stage budgeting problem. We then present a sequential consumer model. We show that the empirical condition for the sequential model to be a good approximation to the two stage model is that interaction effects between products can be determined at the level of multiple-alternative sets without having to consider every pair of alternatives. Our goals for the new model are:

1. Investigate budgeting in this model.

2. Perform an experiment to estimate how close to optimal is human consumer behavior in a single purchase.

In section 3, we consider budgeting. We survey undergraduate students who live in apartments and budget their food consumption without a meal plan. The undergraduate students we survey are much more flexible, according to Thaler's mental accounts (1994), than graduate MBA students surveyed by Chip and Soll (1966). Most of our students use intuitive budgeting procedures and few keep formal records. They improve their budgeting using an incremental adjustment process. Additionally, many students have a feast or famine cycle between expected influxes of income. There is a wide range of student self-ratings on how well they budget, and this self-rating relates to how frequently they monitor the flow of funds in their checking account.

In a sequential model, we can consider the optimality of an individual consumption decision conditional on having made a correct budget decision. In section 4, we perform an experiment on selecting inexpensive ballpoint pens to see how close to optimal student consumers are by comparing a selection decision before and after writing with the pens. We expect to observe a gap between before and after performance. Although students have written with pens since childhood the cost of writing with a new pen is high and new models are constantly entering the marketplace. We provide a measure of how close to optimal the subjects decisions are. We also provide a measure of satisficing performance and show that all but one subjects can be said to exhibit satisficing performance.

In section 5, we present our conclusions.

2 Sequential Consumer Model

Economists have studied computational complexity for at least 30 years, Norman and Jung (1977). Computational complexity is a formal measure of the difficulty in solving a problem, whereby the number of operations necessary to solve the problem are counted with respect to a growth parameter. It is important to note that the operations counted need not be arithmetic operations. They could also be psychological decision heuristics, Norman et al (2004). Computational complexity can also be assessed in an experimental setting by measuring the time required for the human neural network to process a particular type of operation, such as a binary comparison, Norman et al (2003).

We shall start by providing an intuitive example why consumers shop for their bundles item-by-item and not by bundle. To illustrate the problem consider two alternative organizations of a grocery store. To keep the example simple let us assume that grocery store has thirty categories of goods, n , with ten alternatives, m, in each. For example, one category might be types of cereal and another types of milk. To keep the example let us assume that the customer wants one item from each category. In the standard grocery store the goods in each category are organized together and the customer pushes her shopping cart through the isles picking one item from each category. Now let us consider an alternative grocery store where the customer is presented with a line of shopping carts each with a unique combination of thirty goods one from each category. The number of shopping carts the grocer would have to display is $q = m^n = 10^{30}$. If it only took 10 seconds to make a binary comparison between two bundles of 30 items, then it would take only 1.59×10^{23} years to find the preferred bundle. If each bundle were placed in a shopping cart with each cart taking 3 feet then the consumer would have to travel 5.68×10^{27} miles just to view all the bundles. This is the worst-case scenario assuming all shopping carts are budget feasible. Even if on average only 1% of the shopping carts are budget feasible the numbers are still astronomical.

We shall now review the computational complexity of solving the microeconomic consumer optimization problem using a binary comparison operator. In order to avoid considering ϵ approximations to the continues calculus model or a not computable model based on nondenumerable sets, we specify a discrete model. Given modern packaging, most goods are sold in units. Goods like gasoline are discretized in the sense that the consumer purchases gasoline in increments of the smallest coinage, for example cents in the US. Thus, the discrete consumer optimization model is realistic.

We select a discrete utility maximization problem with a separable utility function that has the two-stage budget property Two-stage budgeting dates back to the creation of the separable utility model, Strotz (1957). To see a summary of the literature on separability and budgeting see Deaton and Muelbauer (1982) or Gorman's collected papers edited by Blackorby and Shorrocks (1995). We shall characterize the computational complexity of optimal budgeting for the discrete problem, which has the two stage budget property, described below.

Let us start with the following separable utility function defined over a discrete number of argument values:

$$U(\mu((x)_i)) = U_1([\mu(x_i), 1]) + U_2([\mu(x_i), 2]) + \ldots + U_l([\mu(x_i), l]) \qquad (1)$$

where

$$\begin{aligned} (x)_i &= (x^1_{i_1}, x^2_{i_2}, \ldots, x^n_{i_n}) \\ x^1_{i_1} \in X^1 &= \{x^1_1, x^1_2, \ldots, x^1_q\} \\ x^2_{i_2} \in X^2 &= \{x^2_1, x^2_2, \ldots, x^2_q\} \end{aligned}$$

$$\vdots$$

$$x_{i_n}^n \in X^n = \{x_1^n, x_2^n, \ldots, x_q^n\} \tag{2}$$

,

$$[\mu(x_i), j] = (\mu(x_{i_{\beta(j)}}^{\beta(j)}), \mu(x_{i_{\beta(j)+1}}^{\beta(j)+1}), \ldots, \mu(x_{i_{\gamma(j)}}^{\gamma(j)})) \tag{3}$$

and

$$(x_{i_{\beta(j)}}^{\beta(j)}, x_{i_{\beta(j)+1}}^{\beta(j)+1}, \ldots, x_{i_{\gamma(j)}}^{\gamma(j)}) \in \{X, j\} = X^{\beta(j)} \times \cdots \times X^{\gamma(j)} \tag{4}$$

Given the discrete nature of modern packaging, consumers mostly make discrete purchases of one or more items from a category of close substitutes. X^i might represent a finite set of different types of fruit, boxes of cereal or types of toothpaste. The function $\mu(x_j^i)$ is the number of units of x_j^i selected. Those few items that consumers buy in continuous amounts are discretized by rounding off to the nearest cent, and X^k might present different brands and types of gasoline and the respective $\mu(x_j^k)$ the discrete amount. There are n categories, which are divided into l subsets where $\beta(j)$ is the index of the first category of the jth subset, $\gamma(j)$ is the index of the last category. For simplicity the number of alternatives in each set X^i is equal to q_A and the maximum number of units that can be selected is q_μ. Thus, the number of choices associated with X^i is $q = q_A \times q_\mu$.

We shall assume n is divided into l equal subsets so that the computational complexity of each subproblem is the same; otherwise the computational complexity is dominated by the computational complexity of the largest subgroup. We shall consider values of the growth parameter n such that $\frac{n}{l}$ is integer. Also we shall divide I equally into m integer quantities, $a_1, a_2, \ldots, a_m$ with value $V(a_i) \geq 1$ cent. For example, $V(a_i)$ could equal 1 cent, 1 dollar, or 100 dollars. These m quantities are to be optimally allocated among the elements of $(I)_l$

in the following discrete consumer problem:

$$\max_{(I)_l} \sum_{j=1}^{l} (\max_{[x_i,j]} U([\mu(x_i), j]) \text{ subject to } \sum_{k=\beta(j)}^{\gamma(j)} p^k_{i_k} \mu(x^k_{i_k}) \leq I_j) \text{ and } \sum I_j = I \quad (5)$$

where $p^k_{i_k} > 0$, $I > 0$, and $I_j \geq 0$. We assume that this problem is defined for a single budget time period such as a month if the consumer receives her income monthly. We define it this way because in this book we shall focus on repeated budgeting and search procedures.

Now let consider the relationship to this problem and the two stage budgeting problem for the continuous weakly separable utility function. For the latter problem, Strotz (1957) asked under what condition can we optimally allocate I into $(I)^*_l = I^*_1, I^*_2, \ldots, I^*_l$ where $\sum I^*_j = I$ and solve l smaller optimization problems instead of one large optimization problem. Gorman resolved this issue with a set of Slutsky conditions, see Chapter 2 of Blackorby and Shorrocks (1995).

For the discrete case above, the second stage problem is

$$\max_{[x_i,j]} U([\mu(x_i), j]) \text{ subject to } \sum_{k=\beta(j)}^{\gamma(j)} p^k_{i_k} \mu(x^k_{i_k}) \leq I^*_j \text{ for } j = 1, 2, \ldots, l \qquad (6)$$

where the I^*_js are determined by (4) above. It is straightforward to demonstrate by contradiction that the discrete model has the two-stage budget property, which is that an optimal solution to (4) is and optimal solution to (5) and an optimal solution to (5) is and optimal solution to (4).

We make the following assumptions:

1. **Binary Comparison**: We will consider the set of algorithms that solve (4) by comparing two bundles, $[\mu(x_i), j]$ and $[\mu(x_k), j]$ using a binary ranking operator, $B([\mu(x_i), j], [\mu(x_k), j]$ where $\rightarrow [\mu(x_i), j] \succeq [\mu(x_k), j]$ if $U_j([\mu(x_i), j]) \geq$

$U_j([\mu(x_k), j])$ else $[\mu(x_i), j] \prec [\mu(x_k), j]$. We treat this binary comparison operator as a computational primitive.

2. **Interactions Affects**: There are interactions affects among the goods in each subgroup so that in order to determine the utility of a subgroup bundle, $[x_i, j]$ an algorithm must evaluate $U_j([x_i, j])$. This eliminates additive utility functions, which would greatly simplify the computational problem.

3. **Bundle Organization**: In order to create an algorithm we have to specify how the bundles are organized that the consumer is comparing. For now, we shall assume that the bundles in each category arranged in ascending cost with index $k = 1, 2, \ldots, q^{\frac{n}{l}}$. In the introductory chapter we used an explicit example of this organization with the bundles grocery store. The cost of the kth bundle is represented by $c(k)$ and the preferred bundle in separable group s for the rth level of income is represented by $([\mu(x_*), s], r)$. The rows for the various subgroups are adjacent to each other.

Theorem 3: The worst case and expected computational complexity of the optimal budgeting is $\max(lq^{\frac{n}{l}}, lm^2)$.

Proof: See Norman et al (2001)

For this problem, the computational complexity of optimal budgeting is the maximum of a exponential in the number of alternatives and a quadratic in the number of budget increments. Thus, the two-stage budget property does not lead to a model that is not tractable for humans even aided by current information technology. The first component is a generalization of the intuitive example we provided at the beginning of this section. In determining the optimal budget there is a tradeoff between the number of bundles, which decreases with increasing number of subsets, and the number of possible allocations, which increases with increasing number of subsets. For the sake of discussion we shall ask if l were arbitrary what l would minimize the computational complexity of determining an optimal budget allocation. Given the number of goods in the marketplace $lq^{\frac{n}{l}}$ dwarfs lm^2. Nevertheless, allocating money into categories is quadratic process that is not tractable for unaided humans.

To simplify their optimization problem, consumer search for goods item by item not as bundles. To proceed with the development of a procedural model we specify this sequential search problem and the associated budget problem. We ask under what conditions does item by item search approximate bundle search.

Consumers purchase their goods and services item by item to vastly reduce the computational complexity of the problem to be solved. In this section we create a sequential model of a consumer. In keeping with the tradition of the bundles model we will assume perfect information that implicitly implies zero search costs. During the budget period the consumer solves n item-by-item optimization problems At time t_m the consumer solves the following optimization problem;

$$\max_{x_i^{\beta(j)+k}} U(\mu(x_i^{\beta(j)+k})|H\{(X,j\}) \text{ subject to } p_{i_k}^{\beta(j)+k}\mu(x_i^{\beta(j)+k}) \leq B_{t_m} \tag{7}$$

where $\beta(j)+k \leq \gamma(j)$, $m = \frac{n}{l}j+k$ with $j+1,2\ldots l$ and $k = 1,2,\ldots,\frac{n}{l}$, $H\{X,j\}$ is the history of purchases from the j^{th} subgroup and B_t is the amount budgeted for this purchase. We take up budgeting in the next section.

In the bundles model of the j^{th} subgroup, (6), the assumption is that the consumer considers all possible bundles in the optimization process. In the way we have defined the utility function in (7) it is not additive, but conditional on previous purchases in that subgroup. If a consumer buys a particular type of personal computer and later purchases software packages, the utility of the software alternatives is a function of what operating system runs on the personal computer. But does this imply that all bundles are considered. No, but we must consider at what level in a search are compliments and substitutes considered.

Let us consider some examples. Suppose a grocery list contains cereal and milk to pour over the cereal. The compliments decision is made at the set level of the search. Cereal and milk on a grocery list are abstract entities not particular alternatives in the milk case or cereal display. Empirically in terms of utility the variation in milk in the milk display has almost no affect on the variation of cereal in the cereal display just that milk is needed to enjoy the cereal. Thus the choice of cereal can be made independent of the choice of milk. If one buys a digital camera and then buys a memory card, the type of memory card is determined by which memory card is compatible with the camera and the size of the number card does not affect the quality of the pictures, just the number that can be stored. We assert that the issue of compliments and substitutes in most cases can be resolved at the set level so that a consumer does not need to consider every conceivable bundle in the effort to optimize. This means that to the extent that compliments and substitutes are decided at the set level, a near optimal solution to (3.7) approaches a near optimal solution to (6), given the B_t are optimally determined.

3 Budgeting

Optimal budgeting presents computational problems in excess of human capabilities. As was shown in Norman et al (2001) the computational complexity of allocating I of income into the n b_i is at least a quadratic process. For example, allocation of just 100$ optimally into three categories in $1 increments the consumer would have to consider 5050 alternative allocations. A second problem is that various categories of expenditures have different budget periods. For example, a student has monthly bills, semester bills, usually rents an apartment with a year lease, and generally buys groceries at more frequent intervals than a month. Some expenditures such as clothes can have a variable time lapse between expenditures. We want to know how humans simplify the process.

In order to investigate budgeting we conducted two surveys of undergraduates at our university who lived in rented apartments or houses and were responsible for preparing or buying meals without a meal plan. They were paid $7 each for filling in the 6-page survey. The first survey of 49 students was performed during fall semester 06 and the second survey of 50 students during spring semester of 07. This is an interesting group to study budgeting because they are learning how to budget. Students generally live in a dorm the first year of residence and move into a rented apartment or house where the number of categories that they must budget increases. The students in the two surveys had lived on average 4.2 semesters in rented housing without a meal plan. Because we improved the quality of the second survey questions over the first for some questions we shall consider only the second survey responses.

One simplification to the computational difficulties of optimal budgeting is Thaler's concept of a mental account (1994). Thaler's research has provided numerous examples than money is not fungible meaning that it is allocated into mental accounts that are treated differently. We have no problem with the concept that students treat money at nonfungible because when asked in survey 2, *Do you treat money you earn yourself differently from money you get from your parents? Yes 34 No 16 If Yes, check all that apply: a. I am more frugal with my money because I earned it 22*. The responses to the questions are underlined. Also, in earlier surveys students indicated that they treated windfall gains different from regular sources of income. What we believe needs to be reconsidered is the flexibility of mental accounts and their extent. Heath and Soll (1996) in a study of MBA students showed that they had mental accounts for entertainment, food, and clothing that were implemented in spreadsheets. Our study of undergraduates shows these students are much more flexible than those studied by Health and Soll and they keep fewer accounts of any type. We will show that they budget by making adjustments both within and across accounts. Our theory is that budgeting is an incremental adjustment process, a type of adaptive process, as a consumer solves (3), (4), and (5) once each budget period.

Let us start by characterizing the income sources and financial responsibilities of this group. In this group only 1 financed 100% of his college expenditures and for 17 their parents financed 100%. The underreported source of funds for the average was (1) earned 16.9%, (2) parents 58.5.4%, (3) Loan 11.2%, (4) scholarship 7.66%, and other 2.7% and the average expected debt at graduation was \$8233. The budget responsibilities of students varied greatly. We are interested in what categories for which the student budgeters must allocate funds. We asked students what percent of the expenditures in the following categories did they pay from money in their account regardless of the source of funds. The results for the second survey of 50 students are displayed in the table below:

Category	No.who pay all	No. who pay part	% who pay
Tuition	22	2	48
Rent	35	2	74
Auto	14	13	64
Books	29	3	64
Utilities	34	0	68
Food	33	13	98
Clothing	27	19	96
Entertainment	40	5	90
Phone	10	4	28

The is considerable variation in how students' education is financed and student budget responsibilities. The three categories where students must budget the most are food, clothing and entertainment. A few students have a credit card to buy food, clothing, and entertainment where the bill goes directly to the parents. We focus most of our attention on how students budget for these three categories.

Consider the responses from the second questionnaire. The number of responses is underlined. *Current Budgeting: Do you consider your expenses and account balance before planning for the future? [This could be done formally (e.g. in a spreadsheet) or intuitively (e.g. looking at your account balance and deciding to eat ramen for the rest of the month).]*

16. Do you budget or plan on a regular basis? Yes 37 No 13

17. Check all that apply concerning how often you budget or plan.

a. Weekly? Yes 25 No 15

b. Monthly? Yes 31 No 13

c. Each semester or summer session? Yes 29 No 13

d. When running out of money? Yes 36 No 6

18. Budget Planning: a. Do you anticipate periodic expenses, such as rent or utilities? Yes 45 No 5

b. Do you plan ahead for one-time events, such as trips? Yes 43 No 7

c. If you run low on funds, do you plan what to cut back in the future? Yes 41 No 9

20. Besides monitoring your bank accounts, monitoring your debit/credit cards, and anticipating future expenses, do you use one or more of the following methods to control your expenses?

Method A: I develop intuitive rules to control the amount of money I spend on each purchase. I do not keep records by categories of goods or by individual expenses. For example, I determine how many times a week that I can afford to eat at restaurants and the range of prices I will pay for a meal.

Method B: I budget for various categories of expense, either on paper, on a spreadsheet, or in a program like Quicken. Then I predict my expenses in each category, and if there is a discrepancy between my expense forecast and how much money I have, I plan how to bring the two in line.

Method C: Rent is fixed, utility bills are basically predictable, food varies somewhat, but I am flexible in eating out, entertainment expenses, and car expenses (if applicable). I adjust expenses intuitively.

Method D: Once a week (or other regular period), I check my account balance, determine what bills have been paid, anticipate what needs to be paid, and intuitively consider how to adjust my flexible expenditures (such as food and entertainment).
Method E: As long as the credit card bill that my parents receive this month isnt too much more than they got last month, I dont need to worry much about controlling my expenses.
Check all your methods: Method A 25, Method B 8, Method C 41, Method D 25, Method E 6. For survey 1 the response for the methods was A 17, B 3, C 40, D not asked, E 10. There were minor changes in the wording.

What the question on the type of budgeting our students use clearly indicates that a small minority of undergraduates uses formal budgeting procedures such as a spreadsheet. Most use an intuitive, flexible procedure. While a majority of our students budget on a regular basis their budgeting consists of monitoring current status and considering future expenses. Budgeting for many consists of making rules at the aggregate level, such as how many times a week to eat out.

One aspect of budgeting is monitoring accounts to keep track of the flow of funds. Of these students 22 of the 99 know their bank balance at all times, for example, by balancing their check books with each check. With the internet and voice recognition systems students can monitor their accounts online or using the phone. All of the members of this group have checking accounts, 90 have debit cards, 50 have credit cards where the bill comes to them and 48 have credit cards where the bill comes to their parents. How frequently they monitor account is shown in the table below:

Frequency checked in days	Checking account	Bills	Credit Card
Left blank	2	4	11
1	20	17	19
2	22	13	8
3	9	7	4
4	2	1	1
5	7	9	9
6	0	0	1
7	14	17	17
10	3	5	1
14	4	1	2
15	2	3	5
20	0	1	1
30	13	20	29
60	1	0	0
90	0	1	0

As can be seen by the table above 74 out of the 99 students check their checking account at least once a week. They check which bills have been paid and their credit card balances not quite as frequently as their checking accounts. For most of our students one aspect of budgeting is keeping track of the flow of funds.

Students learn to budget by making adjustments. The response to the following questions is indicated by underlining,

- *23. Since Sep 06, how many adjustments to your spending patterns or income? None 1 Few 37 Several 10 Many 2.*
- *24. In order to reduce overall expenses to income I cut back on overall expenses? Yes 35 No 10*
- *25. In order to balance expenses and income, I increased my income Yes 23 No 26.*

- *26. Did you cut expenses in one category in order to increase expenses in another? (For example, cutting food costs to free up money for entertainment.) Yes 28 No 19.*

- *28. I have increased or plan to increase expenses in one or more categories because I have or will have more money to spend (includes budget estimate too high). Yes 13 No 35.*

- *29. If at the end of the month (or other budget period) you tend to run out of money and cut back to make it to the next period, what categories do you cut?" 39 indicated they cut categories.*

In questions 24, 26, 28, and 29 they were to indicate the categories they adjusted. The number of subjects who adjusted these categories are shown in the following table for the indicated questions:

Category	Q24 Cut	Q26 Cut	Q26 Increase	Q28 Increase	Q29 Cut
Tuition	0	0	0	1	0
Rent	1	0	2	1	0
Auto	2	1	4	2	0
Textbooks	0	2	4	0	1
Utilities	1	1	5	1	1
Food	23	13	0	1	16
Clothing	9	4	3	1	5
Entertainment	21	11	12	6	23
Cell phone	1	0	0	0	0
Other	1	0	1	1	0

Now let us look at how students adjusted their income, food expenses, and entertainment expenses. The responses to the following question are indicated by underlining, *39. Have you gotten more money than you expected to in Sep 06? Yes 21 No 29. If Yes, check all that are applicable: Got a job 9,* *Worked longer hours 8, Pay raise 4, Obtained more money from parents 8, Sold possession on eBay 4 Other 4.* In adjust food expense most students sought to reduce expenses by (1) 29 learned to cook, (2) 26 eat out less, (3) 23 selected less expensive items from the menu, and (4) 23 bought less expensive groceries. Much of the adjustment in reducing food expenses is increasing labor input to reduce cash flow. Another example of where student can use more labor to reduce expenses is to buy textbooks online instead of from the UT bookstore. Thirtyone students indicated they planned to buy textbooks online in the future. Of the 42 students adjusting entertainment expenses, 8 would date less and 10 more, 18 would go out less and 11 more, and finally 24 would go to less expensive events and 3 to more expensive events. Going to the movies is an example where students have a menu of choices such as going to a movie theater, $8, renting a DVD, $4, or checking out a DVD from the library, $0. The adjustment process involves adjusting income, labor input and choices. Beside permanent budget adjustment, many students make adjustments throughout their budget cycle as in survey 1 24 out of the 49 students indicated their budgeting was a feast and famine cycle where they spent more than average the first two weeks and then had to cut back the last week.

The response to the following two questions is underlined, *41. How did you make the adjustments? Check all that apply:*

a. Intuitively adjusting spending in various categories without making an explicit budget. 33

b. Made a budget in my head to adjust expenses. 31 *c. Made a budget on paper to adjust expenses.* 13

d. Made a computer budget to adjust expenses. 10

42. How long did it take you to adjust your budget? Week 15 *Month* 16 *Semester* 5 *Still adjusting* 14.

Humans simplify the budget process using a hierarchical decision structure. For example in making a decision to eat a meal a student can first choose between several alternatives such as cooking or eating out. If she decides to eat out the second decision is at what restaurant. Upon arrival at the restaurant, she checks the menu in order to make a selection of a specific alternative. Such a hierarchical structure vastly decreases the number of specific alternatives, she must consider. It also gives her a mechanism to create simple rules to control expenditures such as a limit on how many times to eat out per week, determination of a set of restaurants within budget limits, and specific limits on how much to spend in a restaurant. Thus with simple rules expenditures can be controlled and using adjustments a student can search for the best definition of rules and tradeoffs between categories of expenditures. On the budget survey over 40% indicated they budget by creating rules.

How well do these students budget. One was to determine is to ask them for their self-rating of their budget skills. *21. Based purely on your subjective opinion and given the amount of time you spend, how well do you budget? Key: Use a 0-10 range, where 0 indicates that you have no grasp of your expenses and 10 indicates that you always know whats going on and allocate money wisely among alternatives. Your self-rating* _____ . The average response was 6.74. The distribution of self-ratings is shown in the table below:

Self-rating value	1	2	3	4	5	6	7	8	9	10
Number selecting above	0	2	1	0	6	8	16	5	10	1

We performed a regression to see if the self-rating was related to how frequently students monitored their checking account.

$$Y_i = a + bX_i + \epsilon_i \tag{8}$$

where Y_i is the i^{th} student's self-rating score, $X_i = \ln Z_i$ and Z_i is the frequency with which the student monitors his checking account and ϵ_i is an independent random variable with 0 mean. The regression results are shown in the following table:

Coefficient	Value	Standard Error	t Stat	P-value
a	7.81	0.40	19.61	0.00
b	-1.38	0.47	-2.93	0.01

The regression shows that the more frequently students monitor their checking accounts the higher their budget skill self-rating. The R^2 for the regression is 0.16 indicating their are also many other factors influencing their self-rating.

4 How Close to Optimal

The 2-stage consumer problem is intractable for a human even with a polynomial assist from a digital computer; therefore, we consider it a waste of time to ask whether consumers determine the mathematical optimum of (5-6). We believe a better question to ask is to investigate the performance of humans in solving (5-6). For this purpose the great advantage of a sequential model is that if we stipulate that the consumer has a good solution to the budget problem we can focus on the performance in making a single purchase.

The first step is choosing a type of purchase to investigate. For this purpose we have considered the purchase of inexpensive ballpoint pens, a product with which students have had experience since elementary school and generally purchase frequently. We selected 41 subjects who indicated that they generally used inexpensive ballpoint pens. When asked which brand and model of the pen they used most often, these students gave an inexpensive model and brand of ballpoint pen. Thus, we were sure that the subjects had prior knowledge of and experience with inexpensive ballpoint pens.

To focus the question we need to ask whether performance converges to optimal for a type of purchase a consumer makes repeatedly. If the introduction of new alternatives into the marketplace is low, the search costs should decline as the consumer uses accumulated knowledge to make the search more efficient. Now let us consider the factors that affect optimal performance in selecting a preferred pen within the budget constraint. From our previous research with pens, Norman et al (2003) and Norman et al (2003a) we know that for most consumers the smoothness with which a pen writes is an important factor in evaluating a pen. Given modern packaging most pens are sold in plastic packages that do not allow the consumer to write with them. Consequently, students can learn how a particular pen writes by using a friends pen or buying one to test it. Such sequential testing is expensive because these pens are sold in packages from 6 to 64 so that a consumer can not simply buy one pen to test it. Repeated searching is governed by Tversky and Kahneman's (1982) prospect function in that people avoid downside risks. This implies that as students find pens they like, they are less and less likely to test pens by buying one. The various manufactures of pens introduce several new pens each year and with R&D the quality of pens is improving. This means that there is no steady state optimal decision. These factors suggest that there is likely to be a gap between actual and optimal performance in selecting pens.

Now let us consider the basic idea behind our experiment. If subjects choice were optimal, then faced with a selection of the 15 pens listed below, they should be able to pick the preferred pen without writing with it as is the case in most stores. We will have subjects write with pens after their first selection to see if they prefer another pen after writing with a set of similar pens. The subjects in our experiment received a flat fee of $8 and the two pens the selected as best before and after writing with the pens. The instructions for the experiment are below:

Experiment Instructions

In front of you is a numbered line of 15 pen packages, each with its own identification number-label. Each package has one corresponding sample pen in front of it.

The hypothetical situation: pretend that you are in an exclusive store for inexpensive ballpoint pens. Assume each pen costs $0.20.

You will be asked to perform three steps: 1. Without writing with any of the pens, use your previous knowledge and/or experience with each pen (if applicable) to determine one best pen simply by looking at the display of pens. 2. Write with each of the 15 pens. 3. After you have tested all 15 pens, determine a new best pen (this pen may or may not be the original best pen). We will give you the pen you identify as the best pen.

You will also be asked for post-experiment pen evaluations. The instructions are on this page. Use the chart on page 2 to provide your answers.

Part I, Without writing: Read step 1, do step one, and then read step 2, and do step 2.

1. In the column PreWrite, write a w in the cell of any pen with which you have written with prior to the experiment and write an o in the cell of any pen you have owned.

2. Without writing with any of the 15 pens, write the number, 1 in the cell corresponding to your estimate of the best pen of the 15 under the column, PreWrite **BEST**.

NOW, WAIT UNTIL THE PROCTOR GIVES YOU SCRATCH PAPER

AND THE PEN YOU IDENTIFIED AS BEST.

Part II: While writing: Read steps 3a, 3b, and 3c below and then start.

3a. First, use the pen you designated as best in step 2 to write abcde on the scratch paper. (You wrote a 1 in the PreWrite **BEST** column in the cell of this pen.) Write C in the appropriate cell of the Acceptable column in the table below if this pen is acceptable for note taking. If not acceptable leave blank.

3b. Use the remaining 14 pens to write abcde with each on the scratch sheet supplied by proctor. (1) Write a C beside each pen in the Acceptable column on the chart below if it is acceptable for note taking and leave blank if not acceptable (2) Write a B beside each pen in the Better column that writes better than the previously declared PreWrite **BEST** pen. Note: A B pen in almost all cases is also a C pen.

3c. **As you proceed, you should determine which of the 15 pens is the best pen** and indicate with number 1 in the appropriate cell of the PostWrite **BEST** column.

CONGRATUALATIONS, THE PROCTOR WILL NOW GIVE YOU THE BEST PEN YOU FOUND BY WRITING AND YOU CAN FINISH WITH PART III.

The results are shown in the two tables below:

Table 1:Prewrite Data for 41 subjects

No.	Pen	Own	Prior Write	Prewrite Best
1	OfficeDepot stick pens Medium 1.0mm	6	5	0
2	PaperMate Grip XL Grip Medium	12	14	5
3	Bic Round Stic Grip Fine	28	9	8
4	PaperMate WriteBros Medium	17	17	0
5	OfficeMax ballpointpens Medium	12	10	0
6	PaperMate Eagle Med 1.2	5	3	0
7	Bic Ultra Round Stic Grip Medium 1.2	29	9	18
8	OfficeDepot ballpoint stick pens Fine	3	6	0
9	Bic Round Stic Medium	25	12	1
10	Target-RoseArt Stick Pens Med	6	0	0
11	OfficeMax medium Grip BallPointPens	5	3	0
12	Bic Crystal Easy Glide Med	22	14	2
13	Target SuperTips	3	4	4
14	Linc Ball Point Pens Medium	3	5	0
15	Target Stick Pens Medium 50	3	5	3

Let us now consider the prewrite information. In the group of 15 pens are 4 pens made by Bic. The subjects had much greater knowledge of these pens than the others. For each of these pens over 1/2 the subjects had previously owned one and most had either owned or written with each of the four. For the last three pens few subjects had either owned or written with them. 29 out of the 41 subjects listed one of the Bic pens as best on the prewrite question with the Bic Ultra Round Stic Grip Medium being in first place with 18 subjects listing it as first.

Table 2:Postwrite Data for 41 subjects

No.	Pen	Acceptable	Better	Postwrite Best
1	OfficeDepot stick pens Medium 1.0mm	25	4	0
2	PaperMate Grip XL Grip Medium	38	3	3
3	Bic Round Stic Grip Fine	38	8	0
4	PaperMate WriteBros Medium	33	6	0
5	OfficeMax ballpointpens Medium	9	1	0
6	PaperMate Eagle Med 1.2	19	6	0
7	Bic Ultra Round Stic Grip Medium 1.2	40	16	16
8	OfficeDepot ballpoint stick pens Fine	18	2	0
9	Bic Round Stic Medium	34	4	0
10	Target-RoseArt Stick Pens Med	27	3	0
11	OfficeMax medium Grip BallPointPens	17	0	0
12	Bic Crystal Easy Glide Med	39	12	4
13	Target SuperTips	32	2	1
14	Linc Ball Point Pens Medium	36	14	1
15	Target Stick Pens Medium 50	40	24	16

Now let us consider the postwrite table. 9 of the 15 pens were considered acceptable for taking notes by 3/4s of the subjects. In the column better than the prewrite pen, the last pen a new import from China by Target garnered 24 votes as being better than the prewrite pen. In the best post write pen, this last pen garnered 16 votes, which is the same as the Bic Ultra round Stic Grip Medium pen.

How close to optimal is difficult to measure because on monotonic transformations of a utility function. Suppose the best postwrite pen has a utility value of 100 and the best prewrite pen a utility value of 64. We can not say the prewrite pen is 64% as good as the post write pen because if we take the square root of the utility values, an acceptable monotonic transformation, the prewrite pen is now 80% as good as the postwrite pen. Instead we ask how many pens did the subject find that wrote better than the prewrite pen. The distribution is shown in the table below:

Table 3: Distribution of Better Pens

number better	0	1	2	3	4	5	6	7+
number subjects	9	6	7	9	5	2	1	2

Of the 32 subjects who found a different best postwrite pen, the average number of better pens was 3.3. One possible explanation for this result is the high cost of writing with pens and the fact that firms in China and India (pen #14) have recently entered this market. It takes time for subjects to gain experience with new pens. Because pen 15 is less than 1/2 the cost of a Bic pen, in time it should gain an increased market share.

Now let us consider Simon's satisficing concept. We will use acceptable for taking notes as a measure for satisficing. With this measure all but one of the subjects picked a acceptable pen in the prewrite question. The subject who found the prewrite pen unacceptable may have confused two Bic pens: #3 and #7.

5 Conclusion

Our paper lays out a sequential approach to consumer theory. How close an approximation solving this model is to solving the bundles optimization model depends on whether compliments and substitutes can be handled at the set level eliminating the need to consider every possible combination in optimization.

With a sequential model the focus shifts from do or do not consumers optimize, but rather how close do they come. The minute you ask this question you must consider individual difference, a topic long studied in psychology, but never in economics. If everyone optimizes there can be no individual difference.

Our budget surveys indicate that students make incremental adjustments to improve their budgeting and their self-awareness of how well they budget is related to how frequently they monitor their checking account. Our experiment suggests that their is a gap between optimal and actual performance even in an inexpensive item that is purchased frequently because of the arrival rate of new technology and the high search costs of writing with alternative pens. In both cases that is a wide variation in individual performance.

This paper is a start and hopefully it has generated your interest to perform research in this line of study.

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