Multi-Product Nonlinear Pricing With Portion Cap Rules: Experimental Evidence

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September 11, 2018

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Abstract

I study the economic impacts resulting from imposing a portion cap rule on one of two products offered by a seller facing demand from privately-informed heterogeneous buyers. Specifically, I look at impacts caused by a binding maximum-quantity limit on: i) consumption of the regulated component, ii) purchases of the unregulated item, and iii) consumer surplus. Hypotheses derived from a bi-dimensional nonlinear pricing predict reductions in consumption of the target component, changes in consumption of the unregulated product by some buyers, and mixed impacts on consumer surplus. Data from a laboratory experiment corroborates the predictions regarding consumption of the regulated good; however, no significant changes in consumption of the unregulated product are found, surprisingly a subset of buyers are better-off after the cap rule while no buyer type is worse-off. The results have implications for food policy discussions around portion cap rules, where the assumption that these regulations negatively impact consumers' well-being largely drives public debate.

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1 Introduction

In this paper, I present an economic analysis of portion cap rules (caps). These policies restrict the default quantities for food products or ingredients judged to have deleterious impacts on human health. One example of such policies is the so-called "New York City soda ban". The advanced plan intended to prohibit food vendors regulated by the city of New York from selling sugar-sweetened beverages (SSBs) in containers exceeding 16 ounces (Kansagra, 2012).[1] Ultimately, this proposal was struck down in court (New York Statewide Coalition of Hispanic Chambers of Commerce v. New York City Department of Health and Mental Hygiene, 2014). Nevertheless, discussions about possible implementations of similar policies in the food retail industry are ongoing and contentious.

Opponents to caps and similar measures argue that consumers' freedom, choice, and well-being are infringed by these interventions. Some of them state that caps could disproportionately impact buyers that prefer to purchase larger quantities of SSBs (Grynbaum (2012); Grynbaum and Connelly (2012)). The implication is that diminishing default sizes will result in lower consumer welfare. This assumption is already shaping public policy, as exemplified by Mississippi's Bill 2687 (2013). This bill interdicts against future restrictions of food sales within the state based upon the product's nutrition information or upon its bundling with other items. However, because sellers engage in sophisticated pricing schemes, even if a regulation modifies consumption it does not necessarily follows that consumers are worse-off. In hope of informing future food policy design, my objective is to provide formal evidence of the economic impacts generated by cap rules when the sellers offer bundles of two products.

In this paper, I look at a seller offering packages containing quantities of two products (A and B) to buyers with private preferences. Suppose that product A is subject to a binding cap. The questions are: i) whether the intervention reduces consumption of the targeted item A, ii) what is the impact on the purchased sizes of the *unregulated* component B, and iii) what is the effect on consumer surplus. To provide answers, I concentrate on studying the seller because surplus distribution and consumption patterns

[1] As a reference, the "small", "medium", and "large" cup sizes typically found in popular American fast-food restaurants contain around 16, 21, and 32 ounces.

are ultimately contingent on the seller's pricing scheme. My analysis of the seller's response to the intervention has two parts: first, I generate analytical predictions from a bi-dimensional nonlinear pricing model; second, I use data from a laboratory experiment to test the model's hypotheses.

In the model, one seller designs a menu of packages (or contracts, in screening theory parlance) from which privately-informed consumers choose their consumption. Each product can be either highly (H) or lowly (L) preferred by the agents. There are four types of buyers that differ in their preferences for the components. The ij-type buyer has preference i for good A, and j for B. The model predicts that without regulation, the seller offers "small-small", "medium-large", "large-medium", and "large-large" A-B combos. Consumer surplus is the largest for the HH-type buyer, and lowest for the LL-type. When the medium HL and LH types' surpluses are positive, they fall between these extremes. If a portion cap rule is enforced such that the seller is required to offer portions of A strictly lower than the "medium" unregulated size, the model predicts: i) all purchased sizes of A would be reduced, including the "small" option; ii) consumption of the unregulated component B increases for the LL-type, and decreases for the HL-type, and iii) information rents for the HH-type are smaller, but they are larger for the LH-type.

I conduct a laboratory experiment to test the predictions listed above. In line with the hypotheses, I find that all consumers lower their consumption of the regulated component, and the LH-type buyer enjoys a larger surplus. On the other hand, contrary to the predictions I find no significant impacts neither on the consumption of product B, nor in the HH-type buyer's earnings.

This research is important and timely because as obesity rates in the United States hover over 30% (Ogden et al., 2014), I expect campaigns against consumption of foods and ingredients associated with obesity and its health consequences to intensify. In effect, not only public health officials have proposed cap restrictions as a food policy tool, some voices within the private sector seem to recognize their potential as a cost-effective method to aid the abatement of obesity (Dobbs et al., 2014). At the same time, campaigns against caps arguing impacts on consumer wellbeing are to be expected. To better construct effective food policies, a strong body of academic knowledge is essential. The academic community and policy officials are relatively well informed about the impacts of tools to regulate food consumption such as excise taxes, labeling requirements, and "nudges" interventions inspired by the behavioral literature. There is however, a relatively smaller literature on the economic consequences of portion cap rules. This research addresses this relative paucity.

The multi-dimensional nature of the pricing problem presented in this paper is an important feature. Most food retailers are multi-product sellers that leverage the wide spectrum of available items they sell to implement sophisticated price-discriminating strategies; importantly they can engage in commodity bundling. Commodity bundling is the screening device where the price of a bundle containing various items in combination is lower than the sum of the prices for the stand-alone products. Alternatively, if two goods are always sold together in packages containing both components (the scheme known as pure bundling), they are said to be bundled if the variance in price across different package presentations is not entirely explained by differences in marginal cost of production[2].

In this document, the seller implements a version of pure bundling. A and B are always consumed together, except in instances where she explicitly sets the quantity of one of the products to zero. This may appear to the reader as a restrictive assumption potentially dampening the predictive power of the model, and its parallelism with what it is observed in the field. I argue this assumption is not as restrictive as it appears, it simplifies experimental implementation, and it can reflect pricing schemes of products we typically do not think of as bundles. For example, consider a soda or soft drinks manufacturer deciding sugar (A)-water (B) combinations. [3] In this case, the contract is a bottle of soda with a particular sugar-water ratio. The model predicts that the seller decides to produce bottles of soda in different presentations: bottles with a one to one sugar-water formula in small and large options to cater to LL and HH-types (the small-small and large-large A-B combos); a "concentrated" formula with a high sugar-water ratio designed for the HL-type's sweet taste (the large-medium A-B combo), and a "light"

[2]For a formal discussion of pricing strategies in markets with imperfectly informed sellers, I refer the reader to Wilson (1993).

[3]In this example, the reader can interpret the "water" ingredient to be the "all ingredients other than sugar" component needed when producing soda.

diluted presentation with low sugar-water ratio serving the health-conscious LH-type (the medium-large A-B combo). Here, the policy takes the form of a restriction in the maximum quantity of sugar allowed in a bottle of soda.

In my analysis, the components are neither complements nor substitutes. This is to emphasize the tension between the multidimensional nature of the incentive-design problem faced by the seller. All changes caused by the cap rule are due to the seller's desire to segment demand. In other words, in this paper I show that a cap rule changes allocation and consumer surplus even when the products are independent and complementarity is absent. Moreover, bundling of non-complements is not an uncommon practice. [4]

In my analysis, I incorporate three stylized observations. First, buyers have private information regarding their preferences. Taste can be considered as exogenous and it is fair to assume that sellers design incentive-compatible menus before any transaction occurs. Second, the seller offers more than one product. This reflects what is observed in the field, where most food retailers are multi-product firms whose pricing strategies include bundling and combo-meal offers; and as in the "bottle of soda as a bundle" mentioned above, even single products can be thought as bundles of ingredients. Lastly, the seller decides the quantities and prices that characterize each package in the menu. In other words, she is not a passive pricer. Following a restriction in quantities, there is no reason to assume that seller will not try to endogenously modify the menu to accommodate the intervention in ways that will impact how seller and buyers divide gains from trade. I am confident these observations are fairly general and cover a wide spectrum of situations encountered in the field, particularly situations in the food retailing and supermarket industries. In the experiment, I allow for flexible contract design; i.e. instead of fixing the number of contracts a given seller can offer thereby limiting their tasks to merely specifying quantities and prices, my subjects taking the role of sellers are allowed to choose the number of bundles they want to offer, their mix of quantities, and their prices. This is consistent with how sellers are assumed to behave in standard screening models.

Even though the nature of the question that initially incited this paper is applied, ab-

[4] For example, several supermarkets engage in pricing strategies that tie gasoline price discounts with consumption of groceries. The reader can consult Wang (2015) for a study regarding this specific instance.

stracting away from institutional details to examine the associated basic problem will prove beneficial. Answering a question whose primitives are highly contingent on particularities of a rather narrow context, although important, does little to further our understanding of a general phenomena (in this case, how do multi-product sellers adjust the pricing scheme given a quantity restriction). I am convinced that comprehending the way in which price-discriminating sellers react to a limit in quantity in a fairly general environment will shed light to our understanding of the basic mechanisms behind the potential outcomes of portion cap rules in the food retail industry and elsewhere.

2 Related literature

This paper contributes to the literatures on food policy design, applied industrial organization, and multidimensional nonlinear pricing.

Because my empirical project relies on the theoretical multi-product nonlinear pricing literature, I present a brief review of the field. Stemming from screening theory, multidimensional nonlinear pricing is notorious for being a source of research queries easy to state but difficult to solve analytically. The early literature on bundling relied on stylized instances and the single-crossing assumption. Adams and Yellen (1976) uses a series of examples to show that mixed bundling is a preferred strategy for the seller when the valuation for the item is negatively correlated. Armstrong (1999) shows that a monopolist can extract almost all possible surplus by price discrimination via a two-part tariff. McAfee et al. (1989) generalized the result of bundling as a preferred strategy by showing that the first order conditions necessary for component pricing to strictly dominate any alternative fail, therefore some form of bundling always does better when the distribution of types is continuous. A growing literature is exploring how robust the early outcomes are to simplifying assumptions. Even "null" results prove a significant contribution to the field; for example, without assuming single crossing, Carroll (2017) shows that when a seller faces a buyer with several dimensions of private information, and the seller knows the marginal distribution of each product of the buyer's type but ignores the joint distribution, then it is in the seller's best interest to engage in component pricing (as opposed to bundling). Venkatesh and Mahajan (2009) offer a review of the bundling literature and discuss how theoretical results are highly sensitive to assumptions on factors such as marginal cost of production, correlation of types, interactions between the components (complementarity, for example) and competition. Because of the complexity implied, Armstrong and Rochet (1999) point out that applied researchers hinder from studying problems where multidimensional screening provides the theoretical framework, despite of the several potential applications of the theory. This paper aims to contribute to the applied literature in multidimensional screening.

The topic of regulating price-discriminating sellers has been intensely studied in the field of industrial organization, although the specific intervention of maximum quantity caps in multi-dimensional screening models seems to be a contribution of mine. The existing literature tends to rely on theoretical predictions. Moreover, both analytical and empirical works either concentrate on the single-product case or rely on a multidimensional version of the single-crossing condition to facilitate the analysis. As a result of adverse selection, price-discriminating firms distort quantity downward along the type space. In a theoretical paper, Besanko et al. (1988) explore the effect of three regulatory measures intending to fix this distortion: minimum quality standards, maximum price regulation, and rate of return regulation. Besanko and co-authors derive conditions under which the rate of return regulation lowers quantity for the high-types; they also demonstrate that maximum price interventions lower quantity for the high-types, while minimum quality standards do not modify the quantity consumed by the buyers with high valuation for the goods. Corts (1995) analytically studies the effect of imposing a price-cap on the lower level of quantity offered by a multi-product monopolist. Corts relies on a multidimensional version of the Spence-Mirrlees single crossing condition to analyze the multidimensional problem with a one-dimensional screening model. He finds mixed results regarding prices paid by different buyer types. In a numerical example where the multi-item single-crossing assumption is relaxed, Corts show how socially suboptimal unbundling may arise as consequence of the intervention. Amrstong et al. (1995) consider two forms of regulations: a cap on the seller's average revenue, and a constraint that forces the seller to keep offering the option to buy a component at the uniform price.

Armstrong and co-authors show that the average revenue constraint is preferred by the seller.

Moving to experimental research, Caliskan et al. (2007) and Hinloopen et al. (2014) are largely concerned with evaluating outcomes from the leverage theory of product bundling, where a multi-product firm competes in two markets, A and B. The firm is a monopolist in market A and faces fringe competitors in market B. The main concern of scholars studying tying is that the multi-product firm may leverage market power from market A to incur in extraordinary rents in market B. In this paper, I am concerned with learning about pricing strategies of a regulated multi-product monopolist with presence in a single market, thus my research speaks to a different, although closely related, literature. An experimental paper testing nonlinear pricing is Hoppe and Schmitz (2015) where the authors test the canonical adverse selection model wherein a seller makes a contract to try to separate a privately informed buyer who has preferences over a low and a high quality item.

More directly related to the topic of regulating food vendors, Wilson et al. (2013) conduct an interesting behavioral study. They aim to determine how a limit on sugary drink portions might affect consumption patterns. The authors put to the consideration of human subjects a hypothetical menu of options, and the subjects were asked to choose how much food they would like to consume. The authors contrast consumption choices made under two types of menus: a baseline menu where the vendor offers soda cups without any regulation, and an active group where the seller replaces large cups (say of 32oz) with smaller containers (say of 16oz). Their main finding is that buyers decide to purchase more soda with the regulated menu featuring the portion cap rule. This study is useful since it provides an insight regarding potential framing effects that could alter subjects' purchase decisions. My paper complements the work conducted by Wilson and co-authors in two dimensions. First, my analysis concentrates on the seller's side of the story. A complete explanation of the consequences of an intervention ought to include analyses of reactions from buyers and sellers. Secondly, my experiment ties monetary rewards to subjects' performance. That is, I reward subjects for taking actions that would make the hypothetical market player they are playing for better off.

My research is an extension of Bourquard and Wu (2016), and Balagtas et al. (2017). These papers analytically and experimentally study the impacts of portion cap rules with single-product sellers trading with privately-informed heterogeneous buyers. They report that a portion cap reduces consumption without affecting consumer surplus. The reason is that as the cap limits quantity, the seller adjusts prices accordingly so as to leave consumer rents unaffected. They also compare cap rules versus taxes and find that taxes do reduce consumer surplus.

3 Theoretical framework

In this section, I introduce a model largely based on the multi-dimensional screening model of Armstrong and Rochet (1999), though I simplify it to facilitate experimental implementation. To illustrate the main features of the theoretical model and how the regulation would be incorporated, I present the characterization for the optimal price schedule before and after the cap. Following succinct discussions of the optimal solutions, I introduce a parametrization of the model.

3.1 Model

The seller is a monopolist producing goods A and B. She offers them in contracts $\{q^A, q^B, p\}$, where p is the price charged for a package containing q^A and q^B units of components A and B, respectively. Buyers' preference for each item remain private information. The ij-type buyer has preference i for good A, and j for B. For each item, buyers can have either high (H) or low (L) preference. There are four types of buyers, denoted HH, HL, LH, and LL. The ij-type buyer is characterized by the vector of taste parameters (θ_i^A, θ_j^B) for $i, j =$ H, L. I assume $\theta_H^A = \theta_H^B \equiv \theta_H$, $\theta_L^A = \theta_L^B \equiv \theta_L$, and $\theta_H > \theta_L$. If the ij-type pays price p_{ij} for a package containing quantities q_{ij}^A and q_{ij}^B, her information rents are:

$$R_{ij} = \theta_i u(q_{ij}^A) + \theta_j u(q_{ij}^B) - p_{ij}$$

The subindex in R, q^A, q^B, and p indicate that the consumer surplus, quantities, and price accrue to the ij-type customer. I assume away interactions between the components. Thus, the two goods are neither substitutes nor complements. In this manner, I emphasize the relationship between the multidimensional incentive constraints and the seller's pricing decisions. This assumption has advantages regarding experimental design that facilitate the interpretation of results. This simplification provides this study with a neutral background where changes across treatments can be confidently attributed to the impact of quantity restrictions on pricing behavior without the confounding effects that complementarity would bring about.

I assume $u(\cdot)$ to be continuous, also $u(0) = 0$, $u'(q) > 0$ and $u''(q) < 0$. Buyer's preferences satisfy the Spence-Mirrlees single-crossing condition. Both, the seller and the buyers have reservation values of zero. I assume both goods to have the same differentiable, increasing and convex cost function $c(\cdot)$. Also, $\theta_H u'(q) > c'(q)$ and $\lim_{q\to\infty}\theta_H u'(q) < c'(q)$, so that trade is possible at least with the HH-type, and total quantity supplied is finite. $\sum_{ij} \beta_{ij} = 1$, so β_{ij} represents the probability that a given buyer is of an ij-type. Lastly, let $\beta_{HL} = \beta_{LH} = \beta$ so that instances HL and LH are equally likely. The seller's expected profit function is:

$$\mathbb{E}[\pi] = \sum_{ij} \beta_{ij} \left[p_{ij} - c(q_{ij}^A) - c(q_{ij}^B) \right]$$

It is useful to represent profit in terms of total and consumer surpluses:

$$\mathbb{E}[\pi] = \underbrace{\sum_{ij} \beta_{ij}[\theta_i u(q_{ij}^A) + \theta_j u(q_{ij}^B) - c(q_{ij}^A) - c(q_{ij}^B)]}_{\text{Expected total surplus}} - \underbrace{\sum_{ij} \beta_{ij}[\theta_i u(q_{ij}^A) + \theta_j u(q_{ij}^B) - p_{ij}]}_{\text{Expected consumer surpluses}} \quad (1)$$

To successfully segment demand and extract as much surplus as possible, the seller must incorporate a set of participation (PC), and incentive-compatibility (IC) constraints. The first group of restrictions ensures that all types are at least indifferent between participating and opting out from trade. These take the general form:

$$\text{PC: } R_{ij} \geq 0 \; \forall \; ij \tag{2}$$

The set of IC constraints are self-selection conditions designed to provide incentives for higher types to choose packages with larger quantities that potentially generate larger profit contributions for the seller. These conditions ensure that the ij-type has no incentives to purchase a package originally intended to serve a kl-type (where $i \neq k$, and $j \neq l$). At the optimum, quantities and prices are such that the ij buyer is weakly better-off by choosing contract $\{q^A_{ij}, q^B_{ij}, p_{ij}\}$ over contract $\{q^A_{kl}, q^B_{kl}, p_{kl}\}$. More precisely, the seller designs these two contracts such that the ij buyer receives a temptation payoff known as information rent. The information rent is exactly equal to the extraordinary rent the ij-type would have gained had he chosen the contract intended for the kl-type from a menu with linear prices. The IC constraints take the following general form:

$$\text{IC: } R_{ij} \geq R_{kl} + \underbrace{u(q^A_{kl})(\theta_i - \theta_k) + u(q^B_{kl})(\theta_j - \theta_l)}_{\text{Rent gained by the } ij\text{-type from posing as a } kl\text{-type}} \quad \forall \; ij \text{ and } kl; i \neq k \text{ and } j \neq l \tag{3}$$

The complete optimization program includes 8 PC and 12 IC restrictions. The seller's goal is to design a menu of contracts $\{q^A_{ij}, q^B_{ij}, p_{ij}\}$ that maximizes expected profit shown in 1 subject to the set of constraints in 2 and 3. The resulting pricing mechanism is incentive-compatible if it satisfies the following monotonicity conditions: $q^A_{HH} \geq q^A_{LH}$, $q^A_{HL} \geq q^A_{LL}$, $q^B_{HH} \geq q^B_{HL}$, and $q^B_{LH} \geq q^B_{LL}$. Intuitively, the quantity of either good is weakly increasing with the corresponding valuation. Additionally, if in the resulting menu of contracts, the quantity of item i increases with the preference for component j, the seller is implementing commodity bundling.

***Definition** 1. In this model, the seller is said to implement **bundling** when, for a given menu of contracts, the quantity of component i increases with preference for j, i.e. when* $q^A_{LL} < q^A_{LH}$, *and/or* $q^A_{HL} < q^A_{HH}$, *and/or* $q^B_{LL} < q^B_{HL}$, *and/or* $q^B_{LH} < q^B_{HH}$.

Bundling will occur when the probability mass function (PMF) of buyer types takes a specific form. The shape of the PMF depends on the correlation of preferences defined as $\rho = \beta_{HH}\beta_{LL} - \beta^2$. One of the main intuitions in the early screening literature is that it is in the seller's best interest to bundle the two products whenever the correlation of preferences is weak enough (Armstrong and Rochet (1999), McAfee et al. (1989), and Adams and Yellen (1976)). In this model, bundling is profitable as long as $\rho < \frac{\beta^2}{\beta_{LL}}$. For this paper's purposes, I will assume that $\rho < 0 < \frac{\beta^2}{\beta_{LL}}$, which is the case when the incentive to bundle is the strongest.

In a "relaxed" version of the problem, the seller ignores the possibility of lower types misrepresenting their preferences. As long as the PC restriction for the LL-type is satisfied, she does not have to worry of the LL buyer purchasing any other package but his, nor about the HL choosing contracts for the LH, or the LL-types, nor about the LH buyer choosing contracts designed to serve the HL and HH buyers. This problem is relaxed in the sense that it does not include all possible incentive and participation restrictions. In fact, only four incentive constraints are relevant. These are represented in figure 1. If $R_{LL} \geq 0$, then all buyer types' PC constraints are satisfied. Thus, only the participation restriction of the lowest type is incorporated into the relaxed program. As I show later, and proved by Armstrong and Rochet (1999), the solution to the simplified program is the solution to the fully constrained problem.

[Figure 1 about here]

In the sections below, I use the relaxed program to characterize the optimal menu of contracts both without and with cap.

3.2 Optimal pricing without regulation

Without regulation, the seller's problem is to design a menu of contracts to maximize 1 subject to the set of restrictions in 4.

$$
\begin{aligned}
&R_{LL} = 0 \\
&R_{LH} = u(q^B_{LL})\Delta \\
&R_{HL} = u(q^A_{LL})\Delta \\
&R_{HH} = \Delta[u(q^A_{LL}) + u(q^B_{LL})] + \max\{[u(q^A_{LH}) - u(q^A_{LL})]\Delta,\ [u(q^B_{HL}) - u(q^B_{LL})]\Delta,\ 0\} \\
&q^A_{HH} \geq q^A_{LH},\ q^A_{HL} \geq q^A_{LL},\ q^B_{HH} \geq q^B_{HL}, q^B_{LH} \geq q^B_{LL} \\
&\text{Where } \Delta \equiv \theta^H - \theta^L
\end{aligned}
\tag{4}
$$

The first step in solving the seller's problem is to find out the exact form of the incentive-compatibility constraint for the HH-type buyer. To provide incentives to the HH-type to truthfully reveal his type, the seller must know which contract other than $\{q^A_{HH}, q^B_{HH}, p_{HH}\}$ could attract the HH buyer strongly enough for him to choose it. Given the correct prices, the HH-type could feel inclined to purchase any of the other three contracts originally designed to serve the LH, HL, and LL-types. Intuitively, this is captured by the three arguments inside the brackets of the max expression in R_{HH} among the equations in 4.

***Proposition** 1. The HH-type buyer incentive compatibility constraint is* $R_{HH} = \Delta[u(q^A_{LL}) + u(q^B_{LL})] + [u(q^A_{LH}) - u(q^A_{LL})]\Delta + [u(q^B_{HL}) - u(q^B_{LL})]\Delta$.

Proof. First, because $\theta^A_i = \theta^B_i \equiv \theta_i$, *for* $i = H, L$, *and the cost schedules of producing both components* $c(\cdot)$ *are identical, quantities will also be symmetric:* $q_{HL} \equiv q^A_{HL} = q^B_{LH}$, $q_{LH} \equiv q^A_{LH} = q^B_{HL}$, *and* $q_{HH} \equiv q^m_{HH}$, $q_{LL} \equiv q^m_{LL}$, *for* $m = A, B$. *Thus, the IC constraint for the HH-type can be written as* $R_{HH} = 2\Delta u(q_{LL}) + max\{[u(q_{LH}) - u(q_{LL})]\Delta, 0\}$

Assume that $R_{HH} = 2\Delta u(q_{LL})$, *this implies* $0 \leq q_{LH} - q_{LL}$. *Using this constraint, program 4 has the following First Order Conditions associated with* q_{LH} *and* q_{LL}:

$$
\begin{aligned}
&[q_{LH}] : \theta_L u'(q_{LH}) = c'(q_{LH}) \\
&[q_{LL}] : \theta_L u'(q_{LL}) = \frac{c'(q_{LL})}{(1 - \frac{\beta + \beta_{HH}}{\beta_{LL}} \frac{\Delta}{\theta^L})} > c'(q_{LL})
\end{aligned}
$$

which imply $0 > q_{LH} - q_{LL}$, *a contradiction.* □

In words, because $\rho < 0$, the fraction of LL-types relative to all other buyer types is low. When this happens, the quantities of A and B in the contract designed for the LL-type are small enough for the HH-type to find this option more appealing than the others. He would rather consider the other two packages. Because in this model taste is symmetric, the quantities of A and B in contracts $q_{HL} \equiv q^A_{HL} = q^B_{LH}$ and $q_{LH} \equiv q^A_{LH} = q^B_{HL}$ are mirror images of each other and are sold at the same price. The HH-type would find both of them equally luring. The seller must take this into consideration and increase the temptation payoff for the HH buyer accordingly.

The first order conditions characterizing the solution to the seller's problem without regulation are in 5.

$$\begin{cases} [q^A_{HH}] : \theta_H u'(q^A_{HH}) = c'(q^A_{HH}) \\ [q^B_{HH}] : \theta_H u'(q^B_{HH}) = c'(q^B_{HH}) \\ [q^A_{HL}] : \theta_H u'(q^A_{HL}) = c'(q^A_{HL}) \\ [q^B_{HL}] : \theta_H u'(q^B_{HL}) = \frac{c'(q^B_{HL})}{\left(1 - \frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta^L}\right)} \\ [q^A_{LH}] : \theta_L u'(q^A_{LH}) = \frac{c'(q^A_{LH})}{\left(1 - \frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta^L}\right)} \\ [q^A_{LL}] : \theta_L u'(q^A_{LL}) = \frac{c'(q^A_{LL})}{\left(1 - \frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta^L}\right)} \\ [q^B_{LL}] : \theta_L u'(q^B_{LL}) = \frac{c'(q^B_{LL})}{\left(1 - \frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta^L}\right)} \end{cases} \quad (5)$$

Naturally, the solution characterized by the FOC above is only relevant if it is the solution to the fully constrained problem. Below, I propose and prove it is. This proof closely follows that in Armstrong and Rochet (1999).

***Proposition** 2.* *Maximizing 1 subject to 4 gives the solution to the seller's fully constrained problem.*

Proof. Proposition 2. Together, $R_{LL} = 0$, the monotonicity constraints, plus the four binding constraints in 1 imply the satisfaction of the following omitted incentive constraints:

- $R_{LL} > R_{LH} + u(q_{LH})(\theta_L - \theta_H)$

- $R_{LL} > R_{HL} + u(q_{HL})(\theta_L - \theta_H)$
- $R_{LL} > R_{HH} + 2[u(q_{HH})(\theta_L - \theta_H)]$

From the first order conditions in 5 it is straightforward to conclude that $q_{HL} > q_{LH}$, thus:

- $R_{LH} > R_{HL} + u(q_{HL})(\theta_L - \theta_H) + u(q_{LH})(\theta_H - \theta_L)$
- $R_{HL} > R_{LH} + u(q_{LH})(\theta_H - \theta_L) + u(q_{HL})(\theta_L - \theta_H)$

Lastly, the single crossing condition implies:

- $R_{LH} > R_{HH} + u(q_{HH})(\theta_H - \theta_L)$
- $R_{HL} > R_{HH} + u(q_{HH})(\theta_L - \theta_H)$

□

Without regulation, the quantities offered are such that:

- $q^{A*}_{HL} = q^{B*}_{LH}, q^{A*}_{LH} = q^{B*}_{HL}, q^{A*}_{HH} = q^{B*}_{HH}, q^{A*}_{LL} = q^{B*}_{LL}$.
- The quantities (q^A_{ij}, q^B_{ij}) purchased for each ij-type are: $(q^{A*}_{HH}, q^{B*}_{HH})$, $(q^{A*}_{HL}, q^{B*}_{LH})$, $(q^{A*}_{LH}, q^{B*}_{HL})$, and $(q^{A*}_{LL}, q^{B*}_{LL})$ for the HH, HL, LH, and LL-type respectively.
- The largest portions are $(q^{A*}_{HH} = q^{B*}_{HH} = q^{A*}_{HL} = q^{B*}_{LH})$. The medium options are $(q^{B*}_{HL} = q^{A*}_{LH})$. The small options are $(q^{A*}_{LL} = q^{B*}_{LL})$.
- Let $q_{HL} \equiv q^A_{HL} = q^B_{LH}$, $q_{LH} \equiv q^A_{LH} = q^B_{HL}$, and $q_{HH} \equiv q^m_{HH}$, $q_{LL} \equiv q^m_{LL}$, for $m = A, B$, the seller's value function is $\mathbb{E}[\pi(\cdot)^*]$, expressed in 6.
- Consumer rents are: $R_{LL} = 0$, $R_{LH} = \Delta u(q^{B*}_{LL})$, $R_{HL} = \Delta u(q^{A*}_{LL})$, and $R_{HH} = \Delta[u(q^{A*}_{LL}) + u(q^{B*}_{LL})] + [u(q^{A*}_{LH}) - u(q^{A*}_{LL})]\Delta + [u(q^{B*}_{HL}) - u(q^{B*}_{LL})]\Delta$.

$$\begin{aligned}\mathbb{E}[\pi(\cdot)^*] = 2\Big\{&\beta_{HH}[\theta_H u(q^*_{HH}) - c(q^*_{HH})] + \beta_{LL}[\theta_L u(q^*_{LL}) - c(q^*_{LL})] \\ &+\beta\big[\theta_L u(q^*_{LH}) + \theta_H u(q^*_{HL}) - c(q^*_{LH}) + c(q^*_{HL})\big]\Big\} \\ &-\Delta\big[(2\beta + \beta_{HH})u(q^*_{LL}) + \beta_{HH} u(q^*_{LH})\big]\end{aligned} \tag{6}$$

Importantly, the profit maximizer seller offers a menu of four package-price contracts, each of these targeting a specific type of buyer. The contracts are graphically represented in figure 2. In this diagram, the solid black dots represent the buyer types, and different background colors represent different contracts.

[Figure 2 about here]

To aid with interpretation, the consumption of both goods and consumer surplus earned by buyer type, are graphically described in figures 3 and 4. I omit scale numbers along the vertical axis of both figures because the height of each bar depends on the parametrization of the model. For some parameter combinations, for example, the LL-type is excluded from participation, and rents for the LL, LH, and HL types are null. However, the essence of the result remains. That is, consumption increases with type, bundling is observed, and consumer surplus weakly increases with buyers' preferences.

[Figures 3 and 4 about here]

3.3 Optimal pricing with portion cap rule

Without loss of generality, suppose that a cap is to be enforced on product A. The seller is not allowed to offer quantities of A larger than $\bar{q}$. Now, the seller's objective is to maximize 1 subject to 2, 3, and the quantity cap (QC) restriction in 7:

$$\text{QC: } q_{ij}^{A} \leq \bar{q} \text{ for } i, j = L, H \tag{7}$$

Restriction QC means that the seller is not allowed to sell quantities larger than $\bar{q}$ to any ij-type buyer. There are three relevant levels of severity at which the cap can be set.[5]

1. Mild restriction: $(q_{HH}^{*} = q_{HL}^{*}) > \bar{q} \geq q_{LH}^{*} > q_{LL}^{*}$.
2. Moderate restriction: $(q_{HH}^{*} = q_{HL}^{*}) > q_{LH}^{*} > \bar{q} \geq q_{LL}^{*}$.
3. Harsh restriction: $(q_{HH}^{*} = q_{HL}^{*}) > q_{LH}^{*} > q_{LL}^{*} > \bar{q}$.

[5] A restriction where $\bar{q} \geq (q_{HH}^{*} = q_{HL}^{*})$ would not have an impact on the seller's optimal pricing scheme.

Taking the unregulated quantities as benchmarks to design the policy, the regulation could limit the portion of good A to be either 1) mild: smaller than the largest options but larger than the medium size; 2) moderate: smaller than the medium option but larger than the smallest alternative; or 3) severe: smaller than the smallest unregulated alternative. In this paper, I study the impact of a moderate restriction.

From equation 3, it can be shown that as the regulation causes both q^A_{HH}, and q^A_{HL} to become smaller, the extraordinary information rent that the LH-type would gain from posing as either HH or HL increases. In other words, as the quantity of product A becomes smaller due to more and more restrictive cap rules, the seller has to be aware of the possibility of the LH-type misrepresenting himself as an HL-type. With a moderate cap, the incentive constraint preventing unfaithful representation of the LH buyer as HL is now binding. This modification renders the downward incentive constraints involving the HH type redundant; that is, if the downward incentive constraints for the LH are satisfied, the HH buyer will not purchase the contracts intended to serve the HL or the LL buyer. The expected-profit maximizing seller must adjust the menu of choices accordingly.

The seller maximizes 8, subject to the LL-type's PC, and the set of incentive constraints depicted in figure 5 and listed in 9. The first order conditions that characterize this problem are in 10.

$$\begin{aligned}\mathbb{E}[\pi] = (\beta_{HH} + \beta)[\theta_L u(\bar{q}) + \theta_H u(q^B_{LH}) - c(\bar{q}) - c(q^B_{LH})] + \\ \beta[\theta_H u(\bar{q}) + \theta_L u(q^B_{HL}) - c(\bar{q}) - c(q^B_{HL})] + \\ \beta_{LL}[\theta_L u(q^A_{LL}) + \theta_L u(q^B_{LL}) - c(q^A_{LL}) - c(q^B_{LL})] - \\ \beta(R_{LH} + R_{HL}) - \beta_{LL} R_{LL}\end{aligned} \tag{8}$$

$$\begin{aligned}&R_{LL} = 0 \\ &R_{HL} = \Delta u(q^A_{LL}) \\ &R_{LH} = \Delta u(q^B_{LL}) + \Delta u(q^A_{LL}) - \Delta u(\bar{q}) + \Delta u(q^B_{HL}) \\ &R_{HH} = 2[\theta_H u(\bar{q}) + \theta_H u(q^B_{LH})] - \Delta[u(q^B_{LL}) + u(q^A_{LL}) + u(q^B_{HL})]\end{aligned} \tag{9}$$

[Figure 5 about here]

$$
\begin{cases}
[\bar{q}]: \;\; \theta_H u'(\bar{q}) = c'(\bar{q}) \frac{\beta_{HH}+2\beta}{\left[\frac{\theta_L}{\theta_H}(\beta_{HH}+\beta)+\beta\left(1+\frac{\Delta}{\theta_H}\right)\right]} \\
[q^B_{LH}]: \;\; \theta_H u'(q^B_{LH}) = c'(q^B_{LH}) \\
[q^B_{HL}]: \;\; \theta_L u'(q^B_{HL}) = \frac{c'(q^B_{HL})}{1-\frac{\Delta}{\theta_L}} \\
[q^A_{LL}]: \;\; \theta_L u'(q^A_{LL}) = \frac{c'(q^A_{LL})}{\left[1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right]} \\
[q^B_{LL}]: \;\; \theta_L u'(q^B_{LL}) = \frac{c'(q^B_{LL})}{\left(1-\frac{\Delta}{\theta_L}\right)}
\end{cases}
\tag{10}
$$

Let the endogenous variables that solve the conditions in 10 be referred to with the double star ($**$) superscript. The results of a harsh cap are:

- The HH-type, and LH-type buyers purchase the same contract with quantities $(\bar{q}^{**}, q^{B**}_{LH})$. The HL, and LL types consumer get quantities $(\bar{q}^{**}, q^{B**}_{HL})$, and $(q^{A**}_{LL}, q^{B**}_{LL})$.
- Importantly, it can be shown that: $q^{B**}_{LH} = q^{B*}_{LH}$; $q^{B**}_{HL} < q^{B*}_{HL}$; and $q^{B**}_{LL} > q^{B*}_{LL}$.
- $q^{A**}_{LL} < \bar{q}$; $q^{B**}_{LL} < q^{B**}_{HL} < q^{B**}_{LH}$.
- Consumer rents compare as follows: $R^{**}_{LL} = R^{*}_{LL}$; $R^{**}_{HL} = R^{*}_{HL}$; $R^{**}_{LH} > R^{*}_{LH}$, and $R^{**}_{HH} < R^{*}_{HH}$.
- The seller's value function is $\mathbb{E}[\pi(\cdot)^{**}]$, expressed in 11. It can be shown that $\mathbb{E}[\pi(\cdot)^{**}] < \mathbb{E}[\pi(\cdot)^{*}]$

$$
\begin{aligned}
\mathbb{E}[\pi(\cdot)^{*}] = (\beta_{HH}+\beta)[\theta_L u(\bar{q}) + \theta_H u(q^B_{LH}) - c(\bar{q}) - c(q^B_{LH})] + \\
\beta[\theta_H u(\bar{q}) + \theta_L u(q^B_{HL}) - c(\bar{q}) - c(q^B_{HL})] + \\
\beta_{LL}[\theta_L u(q^A_{LL}) + \theta_L u(q^B_{LL}) - c(q^A_{LL}) - c(q^B_{LL})] - \\
\beta(R_{LH}+R_{HL}) - \beta_{LL}R_{LL}
\end{aligned}
\tag{11}
$$

The optimal segmentation strategy is depicted in figure 6. The portion cap results in bunching of HH and LH buyers; they purchase the same contract. Under no regulation, the LH and HH types are offered the same large portion of product B, but different quantities of product A.

Surprisingly, the theoretical model suggests that the quantity of the unregulated product B offered to types HL and LL changes. The HL-type is offered less of product B, while the LL receives *more*. This is important to highlight given our initial assumption of no interaction between the components. Even when the products are neither complements nor substitutes, the model predicts that a portion cap rule can change the quantity offered of the unregulated product.

Because the quantity of A offered to the LH and HH-type consumers is indistinguishable, now B is the only variable the seller has the power to manipulate to separate these types. Thus, the seller desires to make the difference between the quantity of B offered to LH and HL to be as large as possible, thus inducing LH to truthfully self-report his type. Increasing the size of the large q^B_{LH} would reduce profit, the alternative is to decrease q^B_{HL}. This is the reason why LH consumes less of B.

The profitability of bundling is behind both the decrease of q^A_{LL} and the increase of q^B_{LL}. Good A is the instrument used by the seller to separate the LH from LL-type buyers, the seller wants to make the gap between q^A_{LH} and q^A_{LL} large. Under a harsh cap the seller cannot increase q^A_{LH}, and she resorts to decrease q^A_{LL}. Because the participation for the LL-type must bind with equality, the seller must change q^B_{LL}. If she decreases q^B_{LL} to equate the new level of q^A_{LL} the profit contribution of this contract would suffer, her only option is to increase q^B_{LL}.

The model predicts two main impacts on consumer surplus per buyer type. A reduction in R_{HH}, and an *increase* in R_{LH}. The reason behind the lowering in surplus for the HH-type is straightforward. The HH-type buyer is worse-off because he is receiving significantly less of a product he values highly and the reduction in price is not large enough to compensate for the decrement in size of the package. The intuition behind the increase in the LH-type's well-being is the following. In the unregulated baseline, the LH-type is "forced" to purchase a medium portion of the product this buyer has a low valuation for. If available, the LH buyer would prefer a "small-large" A-B package which is not available in the baseline. The cap moves the choice set closer to ideal for this buyer type because it reduces the quantity of A this buyer consumes.

To aid with interpretation of the theoretical outcomes, I include figures 7 and 8 depicting consumption and consumer surplus patterns with a cap, respectively. In both figures, I omit the scale in the vertical axis because the point value of each column is contingent on the model's parametrization. In some cases, for example, the LL-type is excluded from participation, and rents for the LL, and HL types are null. However, the essence of the result remains: the model predicts that a severe enough cap on A will reduce consumption of A; increase consumption of B by the LL buyer; decrease consumption of B by the HL type; increase consumer surplus for the LH-type, and reduce consumer rents for the HH-type.

[Figures 7 and 8 about here]

3.4 Hypotheses and parametrization

The subsections above characterize the effects of a cap predicted by a standard multi-dimensional nonlinear pricing model. I summarize these outcomes in the hypotheses below, which I will test with data from a laboratory experiment.

***Hypothesis** 1.* Consumption of good A. Following the implementation of a harsh portion cap rule on product A, all buyer types reduce their consumption of the regulated product A.

***Hypothesis** 2.* Consumption of good B. Implementing a harsh portion cap rule on good A will result in the following impacts on consumption of B: i) the LH and HH-type buyers consume the same quantity of the unregulated product B; while ii) the HL-type purchases less, and iii) the LL-type buyer consumes more of product B.

***Hypothesis** 3.* Expected profit and consumer rents. Imposing a harsh cap on product A will cause the following impacts on surplus: i) the seller's expected profit is smaller; ii) the LH-type gains a larger information rent; iii) the HH-type buyer earns a smaller consumer rent, and iv) the LL and HL-type's consumer surpluses remain unaffected.

Table 1 displays the parameter constellation used during the experiment. With this parameter constellation, without a cap, it is in the seller's best interest to to exclude the LL-type and offer distinct options to each of the other buyer types. The chosen probability combination is fairly generic, and its properties are not particular and can be considered to be fairly representative of other probability-combinations with negative correlation. In figure 9, the 2-simplex in the upper panel shows all possible combinations of probabilities I could have selected. The coordinates within the lightest area correspond to values where $0 < \frac{\beta^2}{\beta_{LL}} < \rho$, and the seller has no incentive to engage in bundling. Coordinates in the second lightest area of the 2-simplex correspond to values of probabilities where $0 < \rho < \frac{\beta^2}{\beta_{LL}}$, thus the incentive to bundle is "weak". The incentive to bundle is the strongest in the dark blue area where $\rho < 0 < \frac{\beta^2}{\beta_{LL}}$. The red line highlights "symmetric" combination of probabilities where $\beta_{HH} = \beta LL$. The combination of probabilities I chose is generic and lies relatively far from "border" and corner regions in the 2-simplex. Moreover, since it is symmetric and it can be expressed with probabilities with only one decimal, this distribution reduces the complexity of the experimental instructions.

[Figure 9 about here] [Table 1 about here]

4 Experimental design

In total, 82 subjects were randomly assigned to either of two experimental treatments *Baseline* or *Cap*. There were three sessions per treatment with 12 to 14 subjects each. Sessions were conducted between October and November of 2017 at Purdue University's Vernon Smith Experimental Economics Laboratory. Payoff functions and the ranges of choice variables can be seen in table 2. Subjects were recruited via ORSEE (Greiner, 2015). The experimental interface was designed with oTree (Chen et al., 2016). The instructions were read aloud by a computer using Google's text to speech application programing interface gTTS 1.2.2. No subject participated in more than one session. The database contains 902 observations, 440 from the *Baseline* group and 462 from the *Cap* treatment.

[Table 2 about here]

All subjects were assigned to the role of a seller and did not interact with any other human participant in the room. A robot played the role of the buyer. The buyer type was randomly and independently assigned each trading period. Experimental earnings were denominated in points, and the exchange rate was 31 points per US Dollar. All sessions had the same structure: first, subjects answered a pre-experimental quiz; second, there were six "training" non-paying trading periods; then, eleven "effective" trading rounds were played; lastly, subjects answered a post-experimental survey. Four out of the eleven effective periods were randomly selected to determine subjects' final payoff consisting of the sum of points earned in the chosen periods. All of the above plus the profit and information rents functions were common knowledge.

The game in each trading period closely mirrors the screening problem described in previous sections. At the beginning of each trading round, the seller could choose to offer from one to four packages; she could also choose not to offer any package at all. Next, the seller was asked to specify quantities and prices. Thus, a menu consisted of up to four packages, each with three arguments: quantity of product A, quantity of product B, and price. Following the design of the menu, the offer was submitted to the computerized buyer for its consideration. The buyer could purchase only one package per period. The buyer would choose the package that maximized its payoff, but would reject the entire menu if all packages resulted in earnings lower than the reservation value of zero. If more than one packages resulted in the same non-negative earnings for the buyer, then the first of these packages (in the order they were submitted) was chosen. The seller and buyer payoffs were determined using the purchased package, if any. If no menu was submitted or if the buyer rejected the entire menu, both parties received zero points. At the end of each trading period, the seller was shown the terms of the menu she offered, the choice made my the seller and her period earnings in points. Figures 10, 11, 13, and 14 show the sequence of screens shown to the subjects. Figure 12 is the calculator subjects had access to during the menu design phase; specifically, during the quantity-price choice sub-phase. In this calculator, subjects could experiment with different quantities-price combinations and learn how these would translate into profit, cost of production, and consumer surplus per type.

Four out of the eleven effective trading periods determined the final experimental earnings for the seller. These were chosen via the following protocol. Labeled from 1 to

330, the experimenter had a list with all possible combinations of four periods. A computer application that randomly chooses numbers between 1 to 330, all equally likely. The application was activated three time. The number that appeared the third time represented the label of the selected combination of paying periods. This was done before subjects started to answer the pre-experimental quiz. The selected paying combination was shown to each subject after they finished with all of their task. If the sum of the four randomly selected periods was negative, the earnings of the subject was set to zero.

5 Results

5.1 Descriptive overview

Before introducing the main results of the study, I first offer an overview of the general patterns encountered in the data. I present evidence that subjects in the baseline submit offers consistent with nonlinear pricing theory. This would grant a degree of confidence that my experimental design appropriately captures the essence of the theory, and that subjects comprehended the instructions.

Specifically, the theory predicts that, without regulation, sellers engage in bundling when facing privately informed buyers with negative correlation of preferences. If I take all of the menus with one or more packages submitted during the baseline treatment, I order the packages within a menu by the sum of their quantities, and average across menus, the result is figure 15. Remember that in the theoretical model of Armstrong and Rochet (1999), bundling is said to exist if the quantity of product j increases with preference for component i, and this is graphically confirmed in figure 15, assuming that the smaller, and second smaller packages target LL and LH types, while the largest and the second largest target HH and HL types, respectively. This is a crude approximation to the sellers' pricing scheme in the sense that it is not immediately obvious which of the two "medium" packages (the options between the smallest and the largest) would be consumed by either the HL or the LH type. Moreover, it ignores the possibility that some sellers engaging in bunching (serving more than one type with a single package), and exclusion. However, it is not one of my objectives to formally test the theory of multidimensional screening. Therefore, I consider the pattern of offered quantities shown in figure 15 to be enough of a proof of sellers attempting to bundle.

[Figure 15 about here]

I turn now to the way in which the menus evolved across periods and look at the possibility of learning. Evidence of learning during the experiment would provide a degree of confidence on the data because it would indicate that the subjects not only understood the instructions, but they took non-random decisions and increased their pricing accuracy as the experiment progressed.

To elicit segmentation and price discrimination, subjects were informed that they were going to be matched with a single buyer each trading round but the type of the buyer would change across periods according to a known probability vector. From the submitted menus, I can infer which packages would each type of buyer would have purchased had he been presented with the menu. These packages and their associated rents are the figures I will be using to test hypotheses during the rest of this document. Tables 3, and 4 show average price and quantities of the packages purchased by each buyer type in the baseline and cap treatments, correspondingly. In both treatments, price and quantities are larger in later periods.

[Tables 3 and 4 about here]

The evolution in prices and quantities would be evidence of a greater degree of pricing accuracy if buyers' information rents are lower in later periods and seller's per-period payoffs are larger later in the experiment. Tables 5 and 6 show that this is generally the case. As the experiment progresses, subjects seem to learn to more precisely price their packages so as to extract more surplus from the buyers.

Table 7 shows that within and across treatments, the market coverage patterns observed in the early part of the experiment are also appreciated later on. That is, the fraction of menus that cover a given buyer type remained stable during the experimental sessions and the market coverage profile observed in the baseline group closely approximates the appreciated in the cap treatment. This, in addition to the results mentioned above, suggest that, on average, subjects did not switch between segmentation strategies, rather they choose a segmentation pattern and, within the selected segmentation scheme, they increased their pricing accuracy as the sessions progressed.

5.2 Major results

I now explore the paper's main research objectives, namely finding what are the impacts that a cap on A has on quantity consumed of both products, and on consumer surplus. For all menus of contracts that subjects submitted, I infer which package would each type of buyer have acquired; how much they would have paid; the profit contribution of each package; the expected profit, and the associated payoffs. In table 8, I show econometric estimates of the portion cap's impact on quantities purchased by each buyer type. I find significant reductions in consumption of A by all buyer types are found. I do not find evidence of a change in consumption of product B by any of the consumer types. These are the main two findings regarding impacts on consumption.

Main Result 1. *According to hypothesis 1, compared to the unregulated baseline, all consumers reduce their consumption of product A.*

Main Result 2. *According to hypothesis 2, the cap rule does not impact the quantity of product B purchased by the HH and LH-type buyers. In opposition to hypothesis 2, neither the HL-type nor the LL-type consumer modified their consumption of good B.*

As stated in result 1, all buyer types reduced their consumption of product A. The estimate on the impact of the cap on consumption of B by the LL-type has the predicted sign, however it is not statistically significant. The data do not support the theoretical hypothesis of a reduction in the consumption of B by the HL-type. Indeed, I do not find evidence of a change in purchases of B by any consumer type.

[Table 8 here]

I turn now to the distributional impacts of the portion cap rule. The econometric estimates of the impact on producer and consumer surplus are in table 9. The main hypotheses are that the LH-type is better off after the cap, while the HH is worse off. To complement the analysis the table also shows the impact on seller's expected profit and per-period profit (observed profit).

***Main Result** 3. In opposition to hypothesis 3: expected profit is not smaller with a cap, and the reduction in consumer surplus earned by the HH-type buyers is not statistically significant. In alignment with hypothesis 3: the LH-type earns a larger surplus, while the HL and LL-type's surpluses remain unchanged.*

As predicted by the model, the LH-type is better off after the cap. Intuitively, this buyer is no longer pressed to buy more of the product he has a low valuation for in order to get the large portion of the good he values the most. The cap moves the set of options closer to the ideal for this buyer's preferences. Contrary to the hypotheses derived from the model, the HH-type buyer is not impacted by the cap. The main reason can be found in table 10. The HH-buyer is buying less of A a good he values largely, however he is also paying less for the package he is purchasing, the reduction in price compensates for the decrement in consumption.

[Tables 9 and 10 about here]

6 Conclusion

In this paper, I present an economic analysis of a form of regulation that imposes a maximum limit on the quantity of a given product a multi-product seller is allowed to offer. In the context of food policy design, such interventions are known as portion cap rules and are an alternative tool for policy makers to regulate the consumption of certain foods and ingredients. To analyze the outcomes of the regulation I look at a two-product seller facing demand from privately-informed buyers. When implemented, the cap is enforced on only one of the goods offered by the seller. I use a model of multi-dimensional nonlinear pricing to derive analytical predictions about the effects of the cap on the consumption of both items and consumer surplus. In the model, there are four types of buyers in the market. The *ij*-type buyer has preference *i* for good A, and *j* for B. Preferences for a given product can be either high (H) or (L).

In the unregulated baseline, the model predicts the seller offers each of the products in "small", "medium", and "large" sizes, and the consumers' information rents weakly increase with their valuation for the products. The model predicts that a portion cap rule forcing the quantity of A to be strictly lower than the "medium" unregulated portion will result in: i) less consumption of the regulated product for all buyers; ii) increased consumption of the unregulated product for the buyer with low preference for both products; iii) reduced consumption of the unregulated product for the buyer with high preference for the regulated good and low preference for the unregulated good; iv) smaller expected profit for the seller; v) larger consumer surplus for the buyer with low preference for the regulated item and high preference for the unregulated good, vi) lower consumer rents for the buyer type with high preference for both products, and vii) no change in consumer surplus for the other buyers. The experimental data confirms i), v), and vii). I do not find significant changes in consumption of product B.

Thus, the experimental evidence suggests that a moderate enough portion cap rule would be successful at reducing consumption of the targeted product from all consumer types, without increasing consumption of the unregulated component. Surprisingly, the experimental data also shows that some buyers are better-off with the cap, while no buyer type is worse off.

The type buyers that are better-off as a result of the policy are consumers with low-high valuations for products A-B. If available, they would prefer a price-discounted small-large A-B package; the closest option for them in the unregulated baseline is a price-discounted medium-large combo; the "small-small" alternative has too little of product B, while the "large-large" package is just too expensive for this buyer. A portion cap rule on good A shapes the set of contracts such that the package designed by the seller to serve the buyers with low-high valuation, is closer this buyers' ideal contract. The buyer with high-high valuations for the A-B goods are surprisingly not worse-off after the policy, this is because during the experimental sessions, this type of buyer paid lower prices for the packages he purchased, the reduction in per-package price is significant and would have left information rents for this buyer unmodified after the cap.

These results have implications for food policy discussions around portion cap rules and similar measures. The assumption that portion cap rules negatively impact consumer well-being is an important driver of public discourse surrounding food policy and at it is least partially shaping public policy, as demonstrated by Mississippi's bill 2687 (2013). Using data from a controlled laboratory experiment, I show that these worries are not justified. A portion can increase consumer well-being for buyers with low preference for the regulated product, who absent a regulation, would be purchasing larger-than-desired options of this product. The reason why some buyers are consuming large-than-desired portions of some products is commodity bundling: to sell you more of the product you really want, sellers design menus with more of the product you do not have a particularly high preference for. The cap reduces the extent to witch this pricing device can be used to segment demand.

Future work would expand the model and experiment with situations where complementarity or substitutability between the package components is allowed. A formal comparison between the impacts of quantity limits and other popular food policy measures such as excise taxes seems to be a natural extension.

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Appendix A: Figures and tables

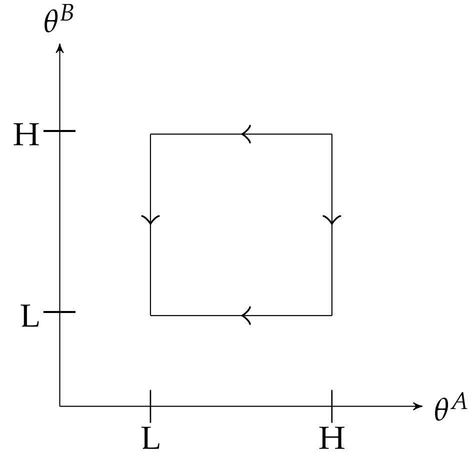


Figure 1: IC constraints in the relaxed problem

Table 1: Parameter values used in this study

Parameter	Value	Description
β_{HH}	0.1	Probability of the buyer being a HH-type
β	0.4	Probability of the buyer being a HL-type
β_{LL}	0.1	Probability of the buyer being a LL-type
θ_H	15	Taste parameter when preference is high
θ_L	10	Taste parameter when preference is low
$\theta_i u(q)$	$\theta_i \sqrt{q}$	Buyer's gross utility
$c(q)$	$q^2/500$	Seller's cost of producing q units of a given good
$\bar{q_A}$	75	Maximum-quantity cap on good A in the cap treatment

The probability of the buyer being an LH-type is also β.

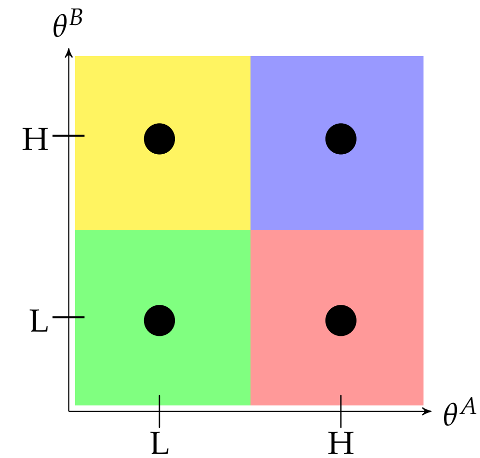


Figure 2: Optimal segmentation without regulation

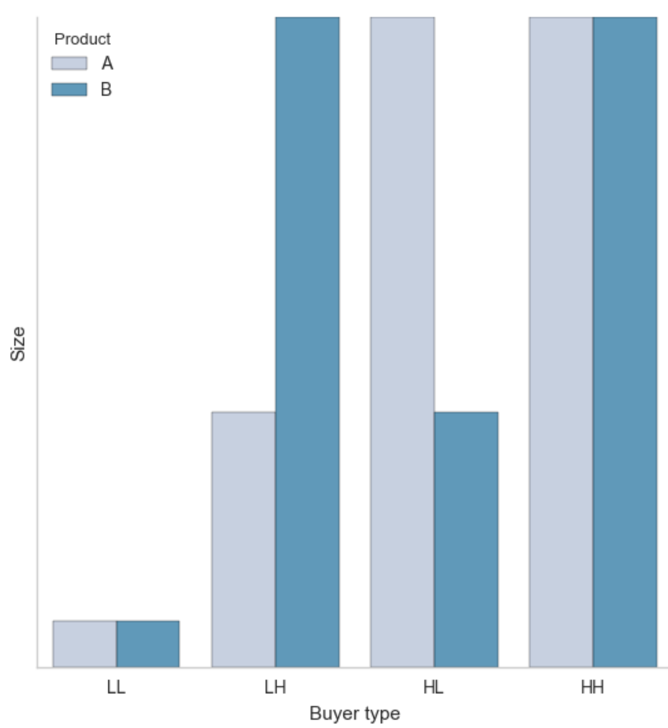


Figure 3: Graphical description of consumption by types - Theoretical baseline

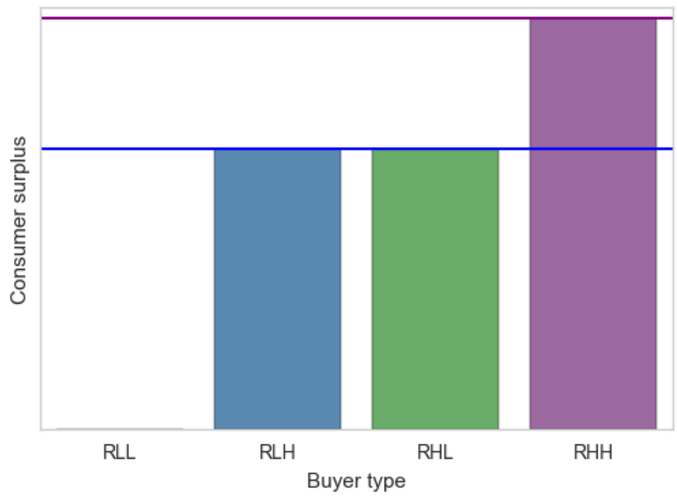


Figure 4: Graphical description of consumer surplus by types - Theoretical baseline

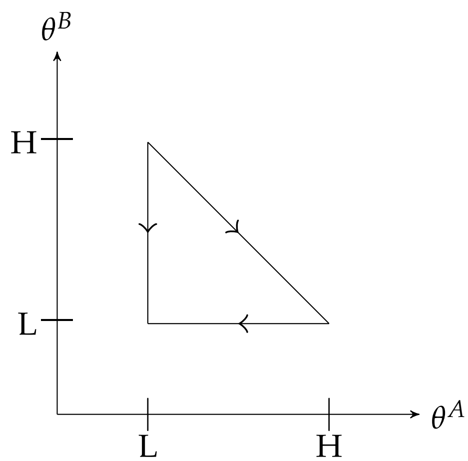


Figure 5: IC constraints in the relaxed problem with a portion cap

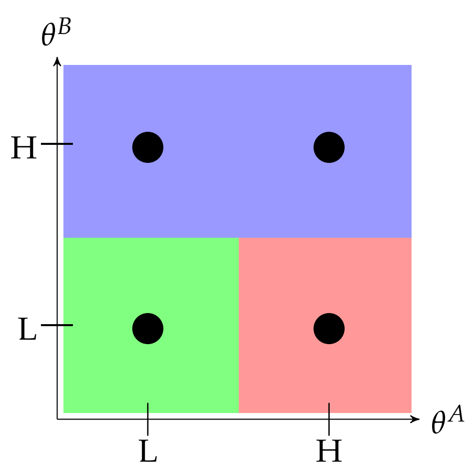


Figure 6: Optimal segmentation with cap

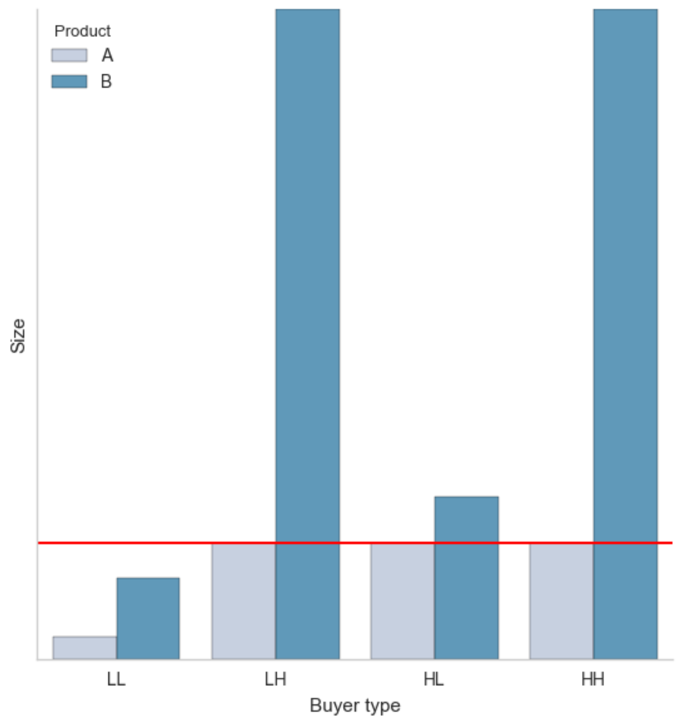


Figure 7: Graphical description of consumption by types - Theoretical cap

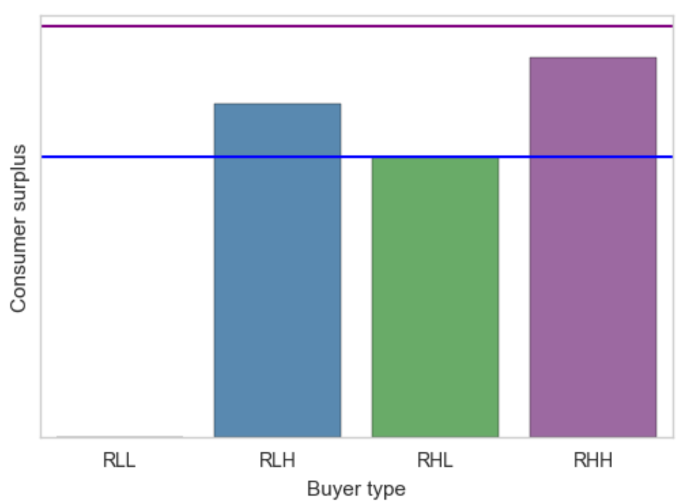


Figure 8: Graphical description of consumer surplus by types - Theoretical baseline

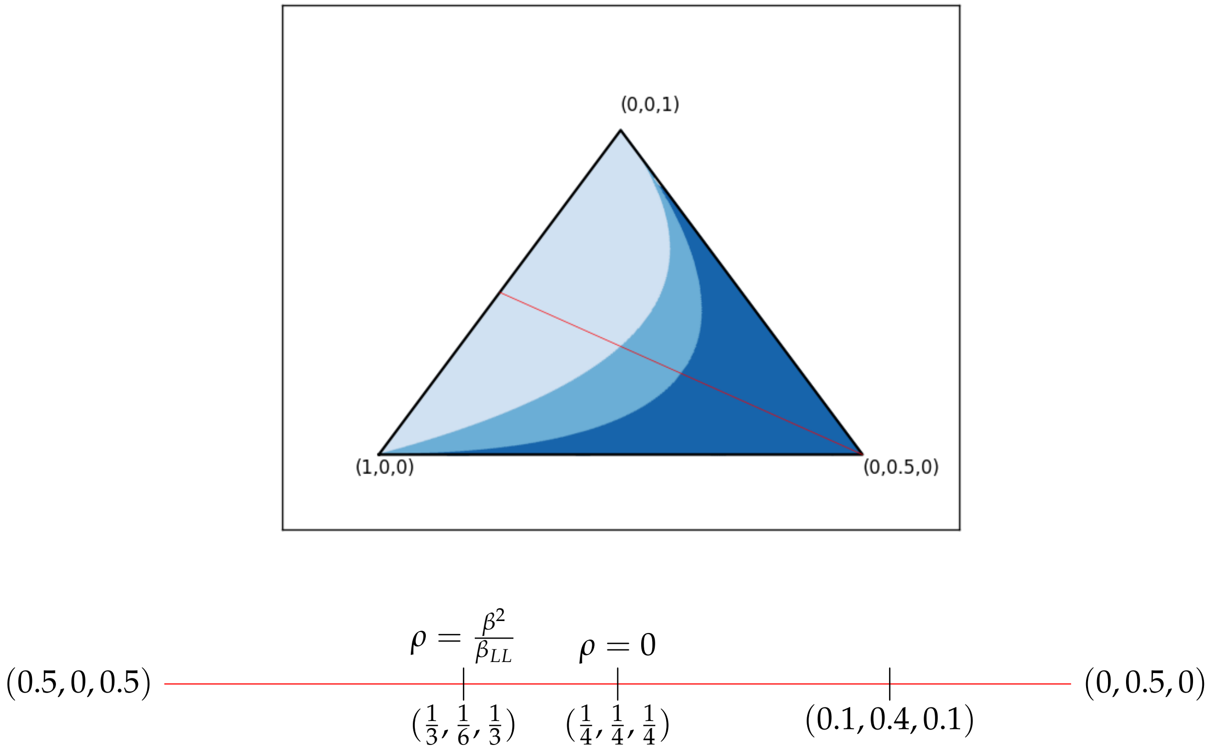


Figure 9: Chosen probabilities of buyer types

Table 2: Experimental treatments

	Payoffs		Choice variables: ranges		
Treatment	Seller	ij-type buyer	Product A	Product B	Price
Baseline	$p - \frac{(q_A)^2+(q_B)^2}{500}$	$\theta^i\sqrt{q_A} + \theta^j\sqrt{q_B} - p$	$[0, \ldots, 250]$	$[0, \ldots, 250]$	$[0, \ldots, 500]$
Cap	$p - \frac{(q_A)^2+(q_B)^2}{500}$	$\theta^i\sqrt{q_A} + \theta^j\sqrt{q_B} - p$	$[0, \ldots, 75]$	$[0, \ldots, 250]$	$[0, \ldots, 500]$

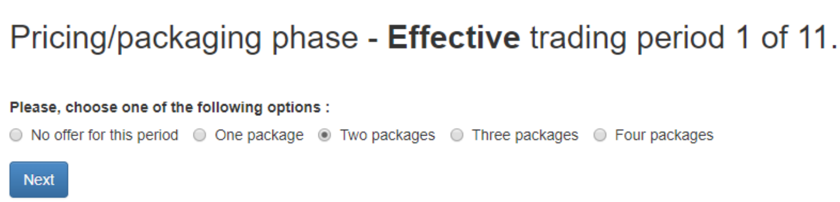


Figure 10: Experimental interface: Menu choice

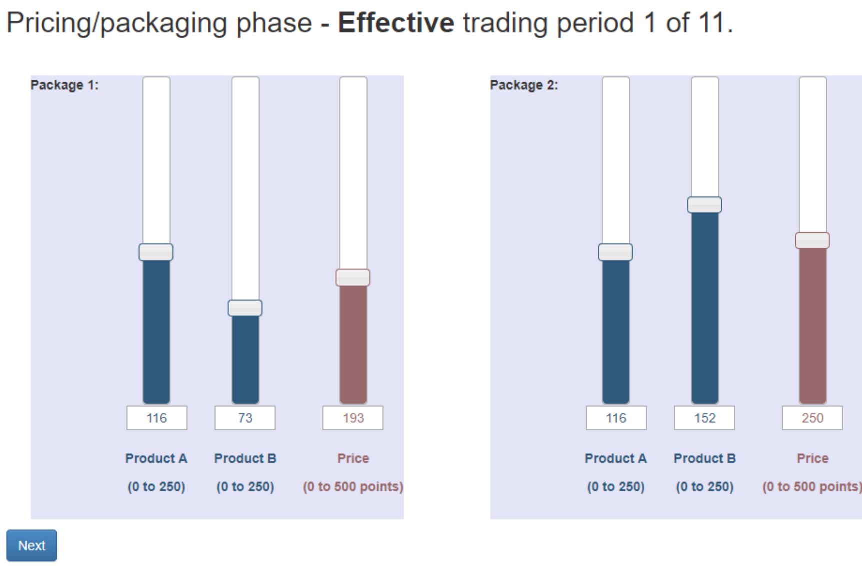


Figure 11: Experimental interface: Quantity and price choice

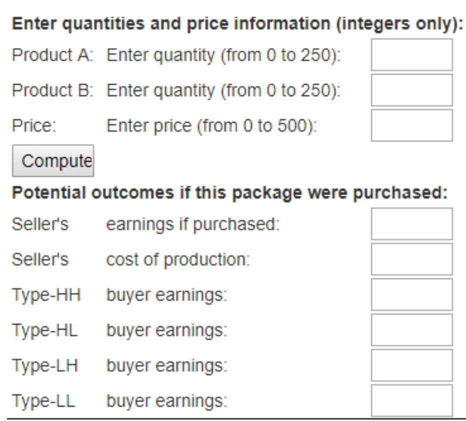


Figure 12: Experimental interface: Quantity and price choice

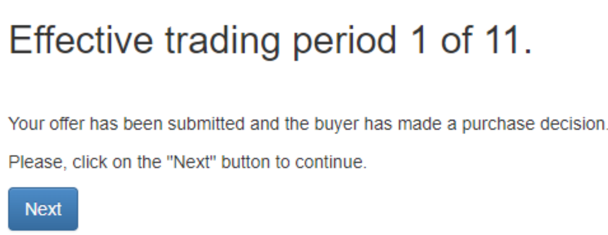


Figure 13: Experimental interface: Offer submitted

Figure 14: Experimental interface: Feedback

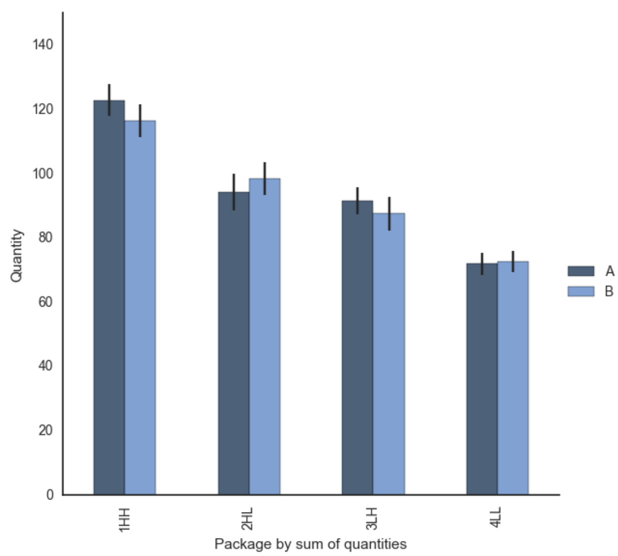


Figure 15: Packages by sum of offered quantities: Baseline

Table 3: Average paid prices and purchased quantities per buyer type: Baseline treatment

	Buyer type			
	LL	LH	HL	HH
All periods:				
Mean price	160.14	209.66	211.35	218.80
Mean q^A	93.42	98.32	117.15	114.10
Mean q^B	90.42	112.93	97.11	109.76
First 5 periods:				
Mean price	145.49	197.63	200.18	204.39
Mean q^A	85.15	92.07	112.38	106.13
Mean q^B	83.47	107.98	91.26	103.69
Last 6 periods:				
Mean price	173.66	219.69	220.75	230.57
Mean q^A	101.06	103.53	121.16	120.60
Mean q^B	96.83	117.05	102.03	114.71

Table 4: Average price and quantities per buyer type: Cap treatment

	Buyer type			
	LL	LH	HL	HH
All periods:				
Mean price	128.97	179.61	169.74	184.22
Mean q^A	41.43	48.57	56.44	55.32
Mean q^B	95.21	119.98	96.89	117.19
First 5 periods:				
Mean price	121.30	170.59	161.18	177.25
Mean q^A	37.50	45.45	53.73	52.97
Mean q^B	88.67	113.75	91.81	112.22
Last 6 periods:				
Mean price	136.26	187.14	176.79	190.03
Mean q^A	45.16	51.19	58.67	57.28
Mean q^B	101.43	125.19	101.07	121.33

Table 5: Average per-period earnings: Baseline treatment

	Number of observed packages			
	0	1	2	3
All periods:				
#Obs/Total (Share)	4/440 (0.9)	251/440 (57.0)	170/440 (38.6)	15/440 (3.4)
Mean R_{LL}	0	10.96	8.51	8.01
Mean R_{LH}	0	40.25	33.81	36.51
Mean R_{HL}	0	41.48	34.04	36.60
Mean R_{HH}	0	90.44	79.59	74.73
Mean payoff seller	0	142.33	144.51	140.93
Mean $\mathbb{E}[\pi]$	0	107.15	110.39	117.62
First 5 periods:				
#Obs/Total (Share)	4/200 (2.0)	111/200 (55.5)	76/200 (38.0)	9/200 (4.5)
Mean R_{LL}	0	16.70	8.10	8.95
Mean R_{LH}	0	48.44	33.76	39.25
Mean R_{HL}	0	49.52	33.53	39.84
Mean R_{HH}	0	96.49	78.13	77.96
Mean payoff seller	0	136.68	142.38	134.61
Mean $\mathbb{E}[\pi]$	0	102.34	109.46	121.51
Last 6 periods:				
#Obs/Total (Share)	0/220 (0.0)	140/220 (63.6)	94/220 (42.7)	6/220 (2.7)
Mean R_{LL}	0	6.41	27.9	6.61
Mean R_{LH}	0	33.76	33.85	32.40
Mean R_{HL}	0	35.10	34.45	31.74
Mean R_{HH}	0	85.65	80.77	69.88
Mean payoff seller	0	146.81	146.23	150.41
Mean $\mathbb{E}[\pi]$	0	110.96	111.14	111.78

Table 6: Average per-period earnings: Cap treatment

	Number of packages			
	0	1	2	3
All periods:				
#Obs/Total (Share)	2/462 (0.4)	300/462 (64.9)	121/462 (26.2)	39/462 (8.4)
Mean R_{LL}	0	15.69	9.85	5.10
Mean R_{LH}	0	52.18	36.68	34.75
Mean R_{HL}	0	35.29	27.9	25.47
Mean R_{HH}	0	87.13	72.34	62.26
Mean payoff seller	0	126.00	135.33	134.41
Mean $\mathbb{E}[\pi]$	0	95.93	100.83	117.38
First 5 periods:				
#Obs/Total (Share)	1/210 (0.5)	133/210 (63.3)	58/210 (27.6)	18/210 (8.6)
Mean R_{LL}	0	17.75	12.17	3.24
Mean R_{LH}	0	53.60	41.71	34.66
Mean R_{HL}	0	36.50	33.22	25.02
Mean R_{HH}	0	87.31	76.13	62.23
Mean payoff seller	0	117.70	127.62	144.21
Mean $\mathbb{E}[\pi]$	0	92.17	102.82	120.87
Last 6 periods:				
#Obs/Total (Share)	1/252 (0.4)	167/252 (66.3)	63/252 (25.0)	21/252 (8.3)
Mean R_{LL}	0	14.05	7.71	6.70
Mean R_{LH}	0	51.05	32.04	34.83
Mean R_{HL}	0	34.32	23.05	25.85
Mean R_{HH}	0	86.99	68.85	62.29
Mean payoff seller	0	132.61	142.43	126.01
Mean $\mathbb{E}[\pi]$	0	98.92	99.00	114.39

Table 7: Market coverage: Participation by buyer type

	Base		Cap
All periods:			
LL-type	221/440 (50.23)	$\approx$	246/462 (53.25)
LH-type	431/440 (97.95)	$<^{*}$	459/462 (99.35)
HL-type	429/440 (97.50)	$\approx$	443/462 (95.89)
HH-type	436/440 (99.09)	$\approx$	460/462 (99.57)
First 5 periods:			
LL-type	106/200 (53.00)	$\approx$	120/210 (57.14)
LH-type	196/200 (98.00)	$\approx$	209/210 (99.52)
HL-type	196/200 (98.00)	$\approx$	200/210 (95.24)
HH-type	196/200 (98.00)	$\approx$	209/210 (99.52)
Last 6 periods:			
LL-type	115/240 (47.92)	$\approx$	126/252 (50.00)
LH-type	235/240 (97.92)	$\approx$	250/252 (99.21)
HL-type	233/240 (97.08)	$\approx$	243/252 (96.43)
HH-type	240/240 (100.0)	$\approx$	251/252 (99.60)

$\approx$ P $\geq$ 0.10, * P $<$ 0.10, ** P $<$ 0.05, *** P $<$ 0.01.

Table 8: Estimates: impact of the quantity cap on per-period quantities purchased per buyer type

	q^A_{HH}	q^B_{HH}	q^A_{HL}	q^B_{HL}	q^A_{LH}	q^B_{LH}	q^A_{LL}	q^B_{LL}
Cap dummy	-58.992***	8.418	-61.200***	0.469	-49.206***	7.454	-44.174***	10.061
	(7.724)	(12.208)	(9.788)	(9.560)	(8.729)	(12.102)	(5.522)	(8.422)
Period	1.639***	1.600***	1.284***	1.684***	1.541***	1.500***	1.880***	2.044***
	(0.399)	(0.464)	(0.228)	(0.362)	(0.462)	(0.440)	(0.399)	(0.674)
Constant	104.360***	99.129***	109.087***	86.499***	88.453***	103.415***	72.4927***	69.600
	(6.246)	(8.383)	(8.510)	(6.486)	(5.721)	(10.415)	(3.542)	(6.054)
Observations	896	896	872	872	890	890	467	467

* P $<$ 0.10, ** P $<$ 0.05, *** P $<$ 0.01. Regressions estimated using multi-level random effects at the session and subject levels. Robust standard errors clustered at the session level in parentheses. Cap dummy takes a value of 1 if the observation belongs to the cap treatment, 0 otherwise.

Table 9: Estimates: impact of the quantity cap on per-period earnings

	Seller's earning		Buyers' earnings			
	$\mathbb{E}[\pi]$	Observed profit	R_{HH}	R_{HL}	R_{LH}	R_{LL}
Cap dummy	-9.290	-13.382	-4.109	-5.683	9.151**	3.388
	(8.719)	(12.179)	(3.903)	(4.946)	(4.227)	(3.548)
Period	1.057***	2.108***	-0.509	-0.966***	-1.071***	-0.796***
	(0.391)	(0.358)	(0.406)	(0.357)	(0.344)	(0.214)
Constant	101.558***	129.345***	87.950***	43.866***	43.703***	14.592***
	(8.442)	(10.601)	(5.338)	(6.214)	(5.534)	(4.275)
Observations	902	902	902	902	902	902

* $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$. Regressions estimated using multi-level random effects at the session and subject levels. Robust standard errors clustered at the session level in parentheses. Cap dummy takes a value of 1 if the observation belongs to the cap treatment, 0 otherwise.

Table 10: Estimates: impact of the quantity cap on per-period prices

	p_{HH}	p_{HL}	p_{LH}	p_{LL}
Cap dummy	-34.163*	-42.081**	-29.17	-18.345
	(19.122)	(19.758)	(18.541)	(15.219)
Period	3.355***	3.291***	3.269***	3.596***
	(0.680)	(0.572)	(0.624)	(0.792)
Constant	198.185***	191.023***	189.076***	118.163***
	(16.693)	(16.926)	(16.496)	(13.467)
Observations	896	872	890	467

* $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$. Regressions estimated using multi-level random effects at the session and subject levels. Robust standard errors clustered at the session level in parentheses. Cap dummy takes a value of 1 if the observation belongs to the cap treatment, 0 otherwise.

Appendix B: Instructions for the *cap* treatment

Experimental Instructions

This is an experiment in the economics of pricing decisions. You are entitled to a $5.00 USD show-up fee which will be paid to you at the end of the experiment. In addition, a clear understanding of these instructions will help you to increase your chances of earning an appreciable amount of money that will be paid to you in cash, in private, at the end of the experiment. During the experimental session, **you are not allowed to talk, laugh or exclaim out loud**. Please, **remain silent during the entire session**. If you have any questions, or need assistance of any kind, raise your hand and an experimenter will help you out. All written information is for your private use only. Do not share information with other participants. Be sure to keep your eyes on your screen only. **Turn off your electronic devices (such as phones, tablets, etc.) now** and put them away during the experiment. Violations of these rules may force us to stop the experiment. Anybody that violates any of these rules will be asked to leave the laboratory and **will not be paid**. We appreciate your cooperation.

Agenda

1. We will go over the instructions.
2. There will be a quiz with 10 questions to make sure everybody understands the experimental instructions. **You will earn 0.20 USD for each question you answer correctly.** All questions will be displayed on your computer's screen. You will have one chance to answer the questions. The correct answers will be displayed in the page following the quiz. Studying the questions you got wrong might help improve your performance during the experiment.
3. After the quiz, you will be working with a fictitious currency called Points. **Points will convert to cash at the end of the experiment at the rate of 31 points = 1 US Dollar**. The next section of the experiment is divided in two parts:
   - First, there will be a set of training trading periods that will allow you to practice without incurring financial risk.
   - Next, there will be a set of effective trading periods. Your performance in these periods will determine your final earnings.
4. You will be asked to answer a post-experimental survey.

Description of the Experiment

In this experiment there will be sellers and buyers. You and every subject in the room are assigned to the role of a seller. You **will not** interact with any other human subject participating in this experiment. You will interact only with the computer assigned to you. Your computer takes on the role of a buyer. You will perform trades. You will retain your role of seller during the entire session. The decisions you make do not affect in any form the results of other participants in the room.

In this market, there are two products: **product A and product B**. The seller will design packages containing quantities of these products. The seller will also specify the prices of each package. These packages are then offered to one potential buyer. The seller and the buyer can obtain earnings from trades. Trades will occur within **trading periods**. There will be many trading periods throughout the course of this experimental session.

In general, the seller's earnings increase with price. Also, the seller's earnings diminish with the quantities of the products contained in the package. This is because it is costly to produce quantities of any product. On the other hand, the buyer's earnings increase with the quantities. However, the earnings made by the buyer decrease with the price paid for the package. **In short, the buyer benefits from high quantity at low prices, while the seller benefits from high prices at low production cost.**

The buyer has a preference for product A and a preference for product B. The buyer can have either a "high" or a "low" preference for each product. How much each product affects the buyer's earnings depends on his type. In general, the buyer benefits from purchasing both products; however, the buyer benefits more from purchasing larger quantities of the product for which he has a "high" preference. There are four possible types of buyers:

Type-HH buyer: This buyer has "high" preference for both products A and B.
Type-HL buyer: This buyer has "high" preference for product A and "low" preference for product B.
Type-LH buyer: This buyer has "low" preference for product A and "high" preference for product B.
Type-LL buyer: This buyer has "low" preference for both products A and B.

In a given period, the type of the buyer will be one of the listed above. **The seller will never be informed about the type of buyer she or he is trading with.** After the seller has designed the menu of packages, the buyer will be presented with the options. **The buyer can decide to either buy one package or not to buy any package at all.** The package agreed upon will determine the earnings for the trading period.

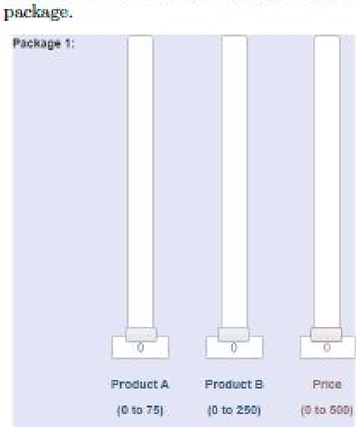
How is the buyer type assigned?
During each trading period you will encounter one buyer. The buyer will be randomly assigned to be of a certain type. This is true for every single trading period. At the beginning of the period, the buyer will be assigned his type according to the following probabilities:

Probability of type-HH: 10%
Probability of type-HL: 40%
Probability of type-LH: 40%
Probability of type-LL: 10%

Note that **the buyer type is not fixed across periods**. You will not know for certain the type of buyer you are trading with. You will only know that the buyer is assigned a type according to the probabilities listed above. The computer will behave like a buyer who knows his type.

Specific Trading Instructions. Each period will be divided into the following phases:

1. **Pricing/packaging phase.** You will be asked to design your menu of packages.

    - *Menu choice*: You will be asked to decide whether to offer one, two, three or four packages. You can also choose not to offer any package at all.
    - *Quantity - Price choice*: For each package you decided to offer, you will need to specify: 1) quantity of product A, 2) quantity of product B, and 3) the price you would like to charge for the package. The quantity of product A can be any integer number between 0 and 75. The quantity of product B can be any integer number between 0 and 250. The price of the package can be any integer number between 0 and 500. If you decide not to offer a package for the period, this step will be skipped. This is an image of the interface used to input the quantities and the price for a package.
    - 

- You can set the desired levels of product A, product B and price by either adjusting the corresponding vertical slider, or by typing into the box right below the corresponding slider. To interact with one of the vertical sliders, you only need to click and hold on its handle, then move your mouse up or down to adjust the handle to the desired level. You can also click on any part of the slider to quickly set the handle at the desired level. You can also use the arrow keys on your computer's keyboard to move the handle one unit at a time. Additionally, below each slider there will be a rectangular box. You can type the desired number of units into the box.

2. **Purchase phase**. If the seller decided to offer at least one package, the computerized buyer will be presented with the menu of options and will have the following alternatives: either purchase one of the packages or reject them all. The buyer cannot buy more than one package per trading period.

   The buyer compares packages with respect to the earnings he would obtain from buying them. **The buyer will choose the package that yields the highest earnings for him**. If the buyer does not buy any package, he earns zero points. The buyer will not buy a package that would result in negative earnings for him. If two or more packages yield the same earnings to the buyer, and they are tied as the most beneficial for the buyer, he will choose the option that appears first in the menu (for example: imagine you offered four options. Suppose that, from the buyer's point of view, packages one and two are tied, and both generate more earnings than packages three and four; then the buyer chooses package one). If the most beneficial package to the buyer results in exactly zero earnings, he will purchase it. In short, **the buyer will purchase the package that maximizes his earnings**.

At the end of the period, you will be presented with a screen displaying the following information: the characteristics of the packages you offered; which package was purchased, and your period earnings. It is recommended to document your performance in the earnings-tracking sheets we provided to keep track of your strategies and performance.

How are earnings calculated?
Prior to making an offer, you will have access to an on-screen calculator where you can compute, for a given quantities-price combination, the following: the earnings that the seller would obtain if the package were purchased; the seller's cost of production, and the earnings that each type of buyer would gain. This calculator appears during the pricing/packaging phase. So you can try different package designs before submitting an offer. The following is how the calculator would appear on-screen:

- **Enter quantities and price information (integers only):**

Product A:	Enter quantity (from 0 to 75):	
Product B:	Enter quantity (from 0 to 250):	
Price:	Enter price (from 0 to 500):	

Compute

Potential outcomes if this package were purchased:

Seller's	earnings if purchased:	
Seller's	cost of production:	
Type-HH	buyer earnings:	
Type-HL	buyer earnings:	
Type-LH	buyer earnings:	
Type-LL	buyer earnings:	

In each period, if the seller decides not to offer any package or if the buyer rejects all options in the menu, then both seller and buyer earn zero points. If you are curious as to how payoffs are affected by quantities and price, keep in mind that **the buyer benefits from high quantity at low prices while the seller benefits from high prices at low production cost.**

For those of you interested in even more details, we explain the equations that define the earnings. Suppose you offered one package containing q_A units of product A and q_B units of product B. Your earnings in points are:

$$\text{Points earned from one sold package} = price - \left(\frac{(q_A)^2+(q_B)^2}{500}\right)$$

Notice that "cost" is determined by the last term. The buyer earnings depend on his type. Notice that you may lose points from selling a package for which the cost of production is higher than its price.

The buyer's earnings are determined by the sum of the valuations gained from consuming each product minus the price he pays:

$$\text{Type-HH earnings} = \left(15 \times \sqrt{q_A}\right) + \left(15 \times \sqrt{q_B}\right) - price$$
$$\text{Type-HL earnings} = \left(15 \times \sqrt{q_A}\right) + \left(10 \times \sqrt{q_B}\right) - price$$
$$\text{Type-LH earnings} = \left(10 \times \sqrt{q_A}\right) + \left(15 \times \sqrt{q_B}\right) - price$$
$$\text{Type-LL earnings} = \left(10 \times \sqrt{q_A}\right) + \left(10 \times \sqrt{q_B}\right) - price$$

Note from the above that the buyer has a much higher valuation for the good he has a "high" preference for compared to the good he has a "low" preference for ($15 \times \sqrt{q}$ versus $10 \times \sqrt{q}$).

How many trading periods will there be?
The trading part of the experiment will be divided in two parts:

1. **First part**: There will be **6 non-paying periods**. We will call these "training" periods. This part provides trading opportunities for you to become familiar with the trading screens and to develop strategies without financial consequences.

2. **Second part**: The second part begins following the training periods. **There will be 11 periods in this part**. We will call these periods "effective" trading periods. Each effective trading period can potentially influence your final earnings. Four out of the eleven effective trading periods will be randomly chosen. **The sum of points that you earned in these four randomly selected trading periods will be converted into cash** and paid to you at the end of the experiment.

How do the paying effective periods get selected?

Labeled from 1 to 330, the experimenter has a list with all possible combinations of four effective periods. These are listed with no particular order. On the laboratory's projection screen, you can see a computer interface that randomly chooses numbers between 1 and 330, all equally likely. The experimenter will activate this interface three times. The number that appears the third time will indicate the label of the combination of paying effective trading periods. This label will be displayed on the projection screen during the entire session. On the list, the experimenter will mark the combination associated with the selected label. He will put the list into a yellow envelope, close the envelope, and leave it on the desk below the projection screen. **Only the experimenter is allowed to open the envelope.** The set of paying effective periods will remain secret until the end of the experiment. Only at the end of the experiment, right before you are paid, the experimenter will privately show you the list of all combinations and the selected combination. Then, the experimenter will proceed to sum the earnings obtained in the randomly selected periods in order to determine your final payoff. If the sum of the four randomly selected effective periods is negative, your trading earnings will be set to zero.