Nonlinear Pricing Under Regulation: Comparing Cap Rules and Taxes in the Laboratory

Jose G. Nuno-Ledesma* Steven Y. Wu† Joseph V. Balagtas†

June 2021

Link to most recent version

Abstract

We report an experiment contrasting the impacts of a tax and a cap rule in a single-product market with privately-informed buyers. Relying on standard nonlinear pricing theory, we evaluate the degree to which consumer choice and surplus are impacted by these measures. In a controlled experiment, we manipulate the policy environment across treatments. With regulations, we aim to reduce the size of the large option by about half the original large quantity. Compared to the regulation-free baseline, sellers facing a cap attempt to separate types with similar frequency. With a tax, subjects are less likely to offer menus with two alternatives. Additionally, we find that consumer surplus remains unaffected under a cap rule, while buyers with high willingness to pay for the product see their surplus diminished by the tax. These results have implications for policy making in the food retail industry and others where authorities aim to regulate consumption while protecting consumer surplus.

PRELIMINARY. PLEASE, DO NOT CITE.

Keywords: experiment, nonlinear pricing, portion cap rule, quantity restriction, tax

JEL classification: C9, D82, L51

*`jnuno@uoguelph.ca`. Corresponding author. University of Guelph. Department of Food, Agricultural & Resource Economics. J.D. MacLachlan Building. 50 Stone Road East. Guelph, Ontario, Canada N1G 2W1.

†{`sywu, balagtas`}`@purdue.edu`. Purdue University. Department of Agricultural Economics. 403 W. State Street West Lafayette, IN 47907.

We benefited from comments from Sven Anders, Timothy Cason, Stephen Hamilton, Alejandrina Salcedo, Bhagyashree Katare, seminar participants at Purdue University, Universidad de Guadalajara, University of Guelph, and Banco de México. We received valuable feedback from attendants to annual meetings of the Agricultural & Applied Economics Association; the Canadian Agricultural Economics Society; the Western Agricultural Economics Association, and the Latin American and Caribbean Economic Association. We thank Tim Cason for providing access to the Vernon Smith Experimental Economics Laboratory. Financial support from USDA-NIFA grant award no. 2014-67023-21852 is gratefully acknowledged. All errors are ours.

1 Introduction

Cap rules set an upper limit on the default quantities at which goods can be offered. In settings where a regulator aims to discourage consumption while protecting consumer surplus, taxes are frequently implemented while caps are often dismissed. This is because intuition suggests that the latter are particularly harsh on buyers. Opponents accuse caps of two main blames: they ostensibly hurt consumers and reduce choice. These issues are rarely raised against taxes and, at most, are not considered to be fatal to their enactment. To judge the degree to which these allegations hold for both interventions in markets where sellers price discriminate, we contrast a cap and a specific tax designed to reduce consumption at the same rate to evaluate their impacts on consumer surplus and number of alternatives in submitted menus. To this end, we leverage standard nonlinear pricing theory to design a laboratory experiment where subjects take the role of single-product sellers serving two types of privately-informed buyers. We manipulate the policy environment across treatments. Compared to the regulation-free baseline, taxation diminishes consumer surplus for one type of buyer and subjects tend to reduce the number of alternatives featured in their menus. These effects are not statistically significant in the treatment with a cap. In other words, with our framework, the mentioned accusations are misplaced: taxation diminishes consumer surplus and reduces the consumer choice set, while the cap rule does not.

The results stem from the seller's desire to segment demand before and after the interventions, particularly through the use of nonlinear pricing. This is a sorting device adopted to mitigate the asymmetric information problem resulting from private preferences. In the canonical case, one buyer (he) holds private information regarding a contractual variable under control of the seller (she); the realization of this information determines his type, and marginal utility of consumption increases with the type. Under these circumstances, it is in the seller's best interest to offer a menu with differentiated price-quantity options so that the buyer voluntarily reveals his type. The sellers' optimal price schedule is concave, implying lower per-unit prices for larger options. The highest type buys his first-best quantity; quantity exhibits downward distortion; the participating buyer with the lowest type is held at his reservation value, and higher types enjoy weakly increasing rents (Maskin and Riley 1984; Myerson 1979; Mussa and Rosen 1978). Neither the tax or the cap rule remove the incomplete information problem faced by the seller. Thus, she modifies her pricing strategy to accommodate the regulations while aiming to maintain incentive compatibility. In addition, taxes and caps affect the seller's scheme in different ways: a specific tax is akin to an increase in marginal cost of production, while the cap limits the quantity space. Thus, the consequences of the pricing adjustments after the enforcement of a measure are not easy to anticipate ex-ante and, as is the case in the setting we examine, they may be counterintuitive.

Examples of industries where nonlinear prices are common include cable television services with "premium" services with substantially more channels than "basic" options and where the price of the alternatives does not increase directly with the number of channels; package delivery services where the per-kilogram fare diminishes as the total weight to be shipped augments, and the consumer packaged goods industry, where "large" choices feature quantity discounts compared to "small" alternatives of the same product.

One example where caps and taxes have been either proposed or implemented is found in the food retail sector. Both casual observation and research suggest that price discrimination is rampant in this industry (Holton 1957; McManus 2007; Bonnet and Réquillart 2013;

Hendel and Nevo 2013). One important motivation for the interventions is that they could discourage the intake of products deemed unhealthy when consumed liberally. Specific taxes are often the first -and frequently the only- option discussed when authorities in health-conscious localities plan their food policy. Take "soda taxes" as an example. In 2013, there were no cities in the United States with an approved tax exclusively targeting sugar sweetened beverages (SSB). Following the first soda tax in Berkeley in 2015, Oakland, Philadelphia, and Seattle enacted their own. Mexico adopted a national tax on SSB in 2014.

On the other hand, because a number of studies link increased consumption to larger portion sizes, caps have arisen as an alternative to regulate food intake (Young and Nestle 2002; Ledikwe et al. 2005; Flood et al. 2006; Rolls et al. 2006). One prominent example is the 2013 New York City's so-called "soda ban." The plan intended to prohibit the sale of SSB in containers exceeding 16 ounces.[1] The measure was ultimately struck down in court. At the time, debates around its potential benefits were contentious. Opponents argued that caps are particularly harmful to consumers and reduce choice.[2] We posit that it is not straightforward to deduce which measure hurts buyers more when sellers implement complex pricing strategies and are likely to modify them after the ordinances come into effect.

We conduct our analysis in two parts. The first is theoretical and relies on a standard nonlinear pricing model. The second part is empirical and there we show results from a controlled experiment. In the analytical discussion, we describe outcomes following adjustments made by a seller implementing perfect profit-maximizing strategies. In other words,

[1]As a reference, the "small" and "large" cup sizes typically found in popular American quick-service restaurants contain around 16 and 32 ounces correspondingly.

[2]Arguments where this premise is present to varying degrees found both in media (e.g. Grynbaum 2012 and Grynbaum and Connelly 2012) and proposed policies; for example, Mississippi's Bill 2687 (2013) interdicts against rules that restrict of food sales based upon the product's nutrition information or upon its bundling with other items (Bourquard and Wu, 2020).

in that section, we delineate results conditional on perfect pricing. We expand the analysis to evaluate how robust the model's predictions are in a setting where actual human behavior takes place. Earlier work documents an empirical regularity wherein sellers adopt simpler non-optimal strategies, forgoing a small fraction of expected profit in return of easier menu design (Chu et al., 2011). Similarly, some human subjects playing as sellers implement sorting schemes that are less complex than the optimal screening strategy even when playing the simplest principal-agent game with incomplete information (Hoppe and Schmitz, 2015). Thus, even if we select parameters so that separating demand is optimal across treatments, some subjects may not do so regardless of the policy environment. Moreover, the model already suggests that taxation closes the gap between the expected payoffs derived from separation and alternative sub-optimal schemes, making them potentially more tempting to human sellers. Therefore, the degree to which the predictions hold in a setting where human participants design the screening menus remains uncertain.[3] To tackle this issue, we conduct a laboratory experiment. The experimental outcomes we report corroborate the theoretical predictions, speaking to the general robustness of the expected patterns: taxed sellers reduce the number of alternatives within menus and leave consumers with less surplus, while the cap does not cause either outcome.[4] Within our frame, this would hold as long as both interventions do not aim to reduce consumption beyond the smallest unregulated alternative.

We remain agnostic about the effectiveness of either taxes or caps to combat obesity. Here, we do not advocate for or against the implementation of either regulatory alternative

[3]This incertitude would remain even if all subjects separate the two buyer types, because it is possible that the participants would not submit the exact profit-maximizing prices and quantities.

[4]We adopt the number of alternatives featured in menus as the metric to evaluate impacts on consumer choice because we take as given that both interventions will eliminate the largest unregulated alternative. In other words, we see a reduction in the number of alternatives as an impact beyond the intended consumption-reduction effect shared by both policies.

in the food retail industry. Our objective is to use an economic experiment, informed by a stylized model, to find whether the ills of reduced choice sets and diminished consumer rents, often used to dismiss cap rules, can also be produced by taxes. The experimental evidence clarifies the manner in which price-discriminating vendors endogenously adapt their pricing schedules under different policy environments. To the degree that sellers in food retailing and other industries adopt nonlinear pricing, and authorities aim to discourage consumption while protecting consumer surplus, the present study can be informative.

2 Related literature

With this study, we speak to a growing literature documenting how both sellers and buyers respond to upper limits in quantity. The few works looking at how sellers accommodate the measure are theoretical exercises (Bourquard and Wu 2020; Nuno-Ledesma 2021). We extend these efforts by analyzing the seller's reaction to taxation. The empirical studies in this area concentrate on identifying consumer-centered aspects of the interventions including potential framework effects and buyer reactance (Wilson et al. 2013; John et al. 2017; Ahn and Lusk 2021). We expand this literature by providing an empirical study of the seller's behavior under regulation. A complete exploration of the outcomes following these measures needs to account for the reactions of both buyers and sellers.

In particular, with this paper we complement previous theoretical work by Bourquard and Wu (2020). They indicate that quantity limits may not affect consumer surplus when price-discriminating sellers separate demand from two buyer types. We take their framework and explore the degree to which this outcome holds under taxation. Further, we expand the analysis with data from a controlled experiment.

Additionally, we contribute to the set of investigations examining the effects of regulating price-discriminating firms in general. The interventions studied with frameworks similar in spirit to our own include minimum quality standards (Besanko et al., 1988); price caps (Sappington and Sibley 1992; Amrstong et al. 1995; Corts 1995), and indirect taxation (Jensen and Schjelderup, 2011). We compare a popular form of intervention (taxation) against caps, which are a relatively less studied measure.

The model we use to aid experimental design implies that taxes reduce consumption. this relationship has been documented by observational studies (e.g. Grogger 2017; Silver et al. 2017; Colchero et al. 2017). However, most of these studies remain silent regarding the underlying mechanisms driving changes in pricing and allocation. Our study offers empirical evidence in support of one such mechanisms: the endogenous response of price-discriminating sellers to accommodate the mandates while maintaining incentive-compatibility.[5]

More broadly, we expand the set of experimental and other empirical studies evaluating conclusions derived from principal-agent models in general (McManus 2007; Huck et al. 2011; Hoppe and Schmitz 2015; Hoppe and Schmitz 2018).

[5]The body of works looking at the impact of soda taxes on weight shows mixed results. Some suggest that there are small impacts contingent on severity of the tax and potential consumer substitution (Aguilar-Esteva et al. 2019; Fletcher et al. 2014;Fletcher et al. 2010a; Fletcher et al. 2010b). Other research points out that the effects may vary depending on key demographic variables (Sturm et al., 2010) and even season (Arteaga et al., 2021). We are not concerned with demonstrating the effectiveness of either regulation on health outcomes. Important to our discussion is the current consensus that taxes do not cause an increase in consumption.

3 Theory

In this section we describe the model we use to derive our hypotheses. We show the characterization of the seller's optimal separating pricing strategies in three policy environments: an unregulated baseline; a scenario with a moderate portion cap, and a third setting where taxation is enforced.[6] The baseline and cap subsections rely on work by Bourquard and Wu (2020), where proofs and further details can be found. Thus, we discuss outcomes regarding the separating equilibrium for both the unregulated baseline and the capped scenarios. We dedicate more time to discuss the seller's three segmentation alternatives (separating, pooling, and exclusive) in the taxed environment.

3.1 Model Baseline Without Regulations in Effect

We begin by establishing a benchmark for the retailer's pricing behavior in the absence of regulation. This allows us to make subsequent comparisons with respect to the impact of the regulations.

The seller (she) offers a menu of different price-quantity combinations of a product to a buyer (he) with private preferences. There are two types of consumers. With probability $\beta \in [0, 1]$, he is a low-type (L-type). With probability $(1 - \beta)$, the buyer is a high-type (H-type). The types are characterized by a taste parameter θ_i for $i = H, L$ such that $\theta_H > \theta_L$. At a given price, the H-type consumes more than the L-type because the former has higher willingness to pay.

When an i-type purchases a package with q_i units of the good (e.g. q_i number of ounces

[6] For completeness, we show the characterization of single-package schemes and discuss the issue of segmentation policy-switching in the appendix.

in the cup) and pays a price $p_i \equiv p(q_i)$, he earns surplus $U_i = \theta_i u(q) - p_i$, where $u(\cdot)$ is a well-behaved utility function.[7] Note that price p_i refers to the serving price, as opposed to per-unit (e.g. per ounce) price. Seller and buyer have reservation values of zero. Cost of production is $c(q) = cq$, where $c'(q) = c > 0$. The seller maximizes her expected profit subject to incentive-compatibility (IC) and participation (PC) constraints:

$$\begin{aligned}
&\underset{(p_H, q_H, p_L, q_L)}{\text{maximize}} \quad \mathbb{E}[\pi] = (1-\beta)\big[p_H - cq_H\big] + \beta\big[p_L - cq_L\big] \\
&\text{subject to:} \\
&\text{PC: } \theta_L u(q_L) - p_L \geq 0 \\
&\text{IC: } \theta_H u(q_H) - p_H \geq \theta_H u(q_L) - p_L \\
&q_i \geq 0, \;\; i = H, L
\end{aligned} \tag{1}$$

The seller's objective function weights the profit contribution (price minus cost of production) of a given size by the probability of the customer being of the corresponding type. As we will show, taxes and caps modify the optimization program in different ways.

We use the classical definition of consumer surplus (gross utility net of price paid) and do not account for potential health benefits from reduced consumption that would be relevant for an application to the case of regulating SSBs. This means that we assume potential health benefits to be null. We maintain this assumption for three reasons. First, much of the opposition against these regulations focused on how they might hurt consumers via reduced choice. Second, to incorporate health benefits to the model, we would need to adopt a precise measure of welfare improvement attributable to the measures. To do so, we would

[7] Throughout the paper, we use the words "cup", "serving" and "package" interchangeably.

be required to accept arbitrary assumptions delineating how exactly lower consumption translates into health benefits. These assumptions could be strategically chosen to produce any outcome. Finally, omitting health benefits makes our results robust to substitution effects in that, even if consumers shift to other unhealthy beverages, we do not run the danger of over-estimating consumer benefits. Indeed, one way to interpret our findings is how consumers might be impacted even if the regulations yield no health or other benefits. In sum, we take the consumer surplus definition that requires the least number of assumptions.

Because the IC and PC restrictions in program 1 play an important role determining the outcomes, we proceed to discuss them. The constraint PC ensures that all buyers are at least indifferent between not participating or purchasing one of the options. To serve both consumer types, only the participation constraint of the L-type is relevant: its satisfaction implies that the H-type finds it individually rational to buy an alternative.

The IC restriction provides incentives for self-selection. We say a menu of two packages is incentive-compatible if the i-type buyer prefers package (p_i, q_i) over an alternative (p_j, q_j) $i \neq j$. In an incentive-compatible mechanism, the quantity increases with the value of the taste parameter θ_i, satisfying the monotonicity condition $q_H > q_L$. Thus, the optimal menu provides incentives for the H-type to purchase the the alternative with larger quantity. The quantities that satisfy the problem's first order conditions are the following:[8]

[8] We use superscripts throughout the theory section to denote solutions to endogenous variables as follows. The stars refer to the policy environment: one star (*) refers to the baseline, two to the market with a cap, and three to the taxed environment. The numbers correspond to the segmentation strategy: number one (1) marks the separating scheme; number two labels the pooling scheme outcomes (when the seller offers one option to serve both types), and the number three denotes results when the seller adopts an exclusive strategy (an option designed to serve H-types only, excluding L-types from participation).

$$
\text{Baseline-separating-quantities} \begin{cases} \theta_H u'(q_H^{*1}) = c \\ \\ \theta_L u'(q_L^{*1}) = \frac{c}{\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right]} \end{cases} \tag{2}
$$

With these outcome, the L-type buyer is held at his reservation value, which we assume to be null ($U_L = 0$). While the H-type buyer receives positive surplus $U_H^{*1} = (\theta_H - \theta_L)u(q_L^{*1})$. The sellers' expected profit is $\mathbb{E}[\pi^{*1}] = \beta[\theta_L u(q_L^{*1}) - cq_L^{*1}] + (1-\beta)[\theta_H u(q_H^{*1}) - (\theta_H - \theta_L)u(q_L^{*1}) - cq_H^{*1}]$. Therefore, total surplus is $T.S. = \mathbb{E}[\pi^{*1}] + U_H$. The profit-maximizing schedule allocates larger quantity to the buyer with higher willingness to pay, granting him positive surplus. The L-type is held at his reservation value. The solution allocates to the H-type his first best quantity because this type's marginal willingness to pay equates marginal cost of production. On the other hand, the L-type buyer receives less than his first-best quantity.

3.2 Model With Cap Rule

With a cap limiting the maximum quantity to an arbitrary level $\hat{q}$, such that $q_L^{*1} \leq \hat{q} \leq q_H^{*1}$, the seller's problem is still 1, but with an additional portion cap restriction (PCR):

$$
\text{(PCR): } q_i \leq \hat{q} \ \text{ for } \ i = L,\, H \tag{3}
$$

We consider this range of regulations because only restrictions where $\hat{q} \leq q_H^{*1}$ are of economic interest. We assume that the regulation is set at a level larger than or equal to the unregulated small size (i.e. $q_L^{*1} \leq \hat{q}$). Our analysis is consistent with moderate restrictions that do not set the limit below the quantity contained in the small regulation-free alternative.

At the solution, the quantities satisfy:

$$\text{Cap-separating-quantities} \begin{cases} \theta_H u'(q_H^{**1}) \geq c, \text{ where } q_H^{**1} = \hat{q} \\ \theta_L u'(q_L^{**1}) = \frac{c}{\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right]} \end{cases} \tag{4}$$

With a menu of two packages, the L-type buyer gains no rents. The H-type consumers earn $U_H^{**1} = (\theta_H - \theta_L)u(q_L^{**1})$. Expected profit is $\mathbb{E}[\pi^{**1}] = \beta[\theta_L u(q_L^{**1}) - cq_L^{**1}] + (1 - \beta)[\theta_H u(\hat{q}) - (\theta_H - \theta_L)u(q_L^{**1}) - c\hat{q}]$. Total surplus is $\beta[\theta_L u(q_L^{**1}) - cq_L^{**1}] + (1 - \beta)[\theta_H u(\hat{q}) - (\theta_H - \theta_L)u(\hat{q}) - c\hat{q}] + (\theta_H - \theta_L)u(\hat{q})$.

In brief, if the size restriction limits the H-type's serving but not the L-type's. There is no impact on consumer surplus. Profit is negatively impacted. The cap will reduce the quantity offered to the H-type but not the portion size served to the L-type. Intuitively, as the regulation moves the size of the large package down, the seller adjusts the price of the large package accordingly in an effort to keep incentive compatibility and continue to separate buyers by their taste.

3.3 Incorporating Taxation

We expect a tax to have two effects. First, it could directly impact package sizes and prices. Second, it may indirectly cause the retailer to change her segmentation strategy (from separating to pooling or exclusive).

Let us define a tax regime (τ_s, τ_v) as any mixture of specific $(\tau_s \geq 0)$ and *ad valorem* $(\tau_v \in [0, 1))$ taxes, such that both of them are not zero at the same time. To avoid divisions by zero later on, we exclude combinations where $\tau_v = 1$. Specific taxes modify the objective function in a way akin to a change in the cost function. *Ad valorem* taxes alter the objective function in two ways: by modifying the cost function and scaling down expected profit. Under taxation, the seller solves:

$$\max_{q_L, q_H} \ \mathbb{E}[\pi] = (1-\tau_v)\Big\{(\beta)\big[\theta_L u(q_L) - \Psi_L\big] + (1-\beta)\big[\theta_H u(q_H) - (\theta_H - \theta_L)u(q_L) - \Psi_H\big]\Big\} \quad (5)$$

where $\Psi_i \equiv (\tau_s q_i + c q_i) \div (1-\tau_v)$ is the effective cost function under taxation. Let $\psi \equiv \frac{d\Psi_i}{dq_i} = (\tau_s + c) \div (1-\tau_v)$ denote effective marginal cost. First order conditions are:

$$\begin{aligned} &\text{FOC}[q_H] : \frac{\partial\,\mathbb{E}[\pi]}{\partial q_H} = (1-\tau_v)(1-\beta)[\theta_H u'(q_H) - \psi] \leq 0 \\ &\text{where} \quad q_H \geq 0 \quad \text{and} \quad \frac{\partial\,\mathbb{E}[\pi]}{\partial q_H} \cdot q_H = 0 \end{aligned} \quad (6)$$

$$\begin{aligned} &\text{FOC}[q_L] : \frac{\partial\,\mathbb{E}[\pi]}{\partial q_L} = (1-\tau_v)\big\{\beta(\theta_L u'(q_L) - \psi) + (1-\beta)[-(\theta_H - \theta_L)v'(q_L)]\big\} \leq 0 \\ &\text{where} \quad q_L \geq 0 \quad \text{and} \quad \frac{\partial\,\mathbb{E}[\pi]}{\partial q_L} \cdot q_L = 0 \end{aligned} \quad (7)$$

These equations characterize the optimal solution with taxation. We proceed with a delineation of the outcomes under different segmentation strategies.

Separating Pricing Strategy with Taxation

When the seller aims to serve both buyer types, they are offered options such that $q_i > 0$, $i = H, L$. Thus, equations 6 and 7 hold with equality:

$$\text{Tax-separating-quantities} \begin{cases} \theta_H u'(q_H) = \psi \\ \\ \theta_L u'(q_L) = \psi + \left(\frac{1-\beta}{\beta}\right)(\theta_H - \theta_L)u'(q_L) \end{cases} \tag{8}$$

The *effective* marginal cost of supplying a large package equals the H-type's marginal utility of consumption. Thus, while there is distortion relative to the baseline case, there is "no distortion at the top" relative to the effective marginal cost. Note however that, in effect, the higher type is receiving a quantity below his first-best. The seller continues to distort the size of the option for the L-type. Relative to the baseline, both buyer types get less than their first-best optimal quantities because the effective marginal cost is altered by the tax so that $\psi > c$. The price rules associated with this case are $p_L^{***1} = \theta_L u(q_L^{***1})$, and $p_H^{***1} = \theta_H u(q_H^{***1}) - (\theta_H - \theta_L)u(q_L^{***1})$. Earnings are:

$$\text{Tax-separating-information rents} \begin{cases} U_L^{***1} = 0 \\ \\ U_H^{***1} = (\theta_H - \theta_L)u(q_L^{***1}) \end{cases} \tag{9}$$

$$\pi^{***1} = (1-\tau_v)\Big\{(\beta)[\theta_L u(q_L^{***1}) - \psi q_L^{***1}] + (1-\beta)\big\{[\theta_H u(q_H^{***1}) - (\theta_H - \theta_L)u(q_L^{***1})] - \psi q_H^{***1}\big\}\Big\} \tag{10}$$

In sum and compared to the unregulated benchmark, the size of both packages is smaller. H-type consumers still receive rents, although these are smaller so there is welfare loss. L-types are held at their reservation values, and the seller sees her expected profit unambiguously diminished. While it may seem counter-intuitive that prices are lower after a tax, keep in mind that we focus on per-serving size prices as opposed to per-unit prices (e.g. price per-ounce).[9]

Pooling Strategy with Taxation

Recall that to accommodate the intervention, the seller can modify both the endogenous variables (prices and quantities) and/or the segmentation scheme. The question arises, then, as to whether the seller will maintain a separating strategy following the tax or if she will pivot to a single-option type of strategy. We first consider the case where the seller offers one option to serve both consumer types with a "one-size-fits-all" type of strategy. The retailer's optimization problem can be written as follows:

$$\begin{aligned} &\max_{p,q}\ \mathbb{E}\left[\pi\right] = (1-\tau_v)t_L - (\tau_s + c)q_L \\ &\text{subject to:} \\ &\text{IRL} : \theta_L u(q) - t_L \geq 0 \end{aligned} \tag{11}$$

The optimization conditions imply:

$$\text{Tax-pooling-quantity} \begin{cases} \theta_L u'(q^{***2}) = \psi \end{cases} \tag{12}$$

While equation 12 implies marginal benefits are equal to the effective marginal cost, recall that ψ is the effective marginal cost post-tax. Thus, the L-type does not get his first-best level of consumption. The value functions for the seller and buyers are:

[9] In the textbook problem with complete information, a tax causes the demand function to shift downward and lead to a higher uniform price for all units. However, in the nonlinear pricing problem, a serving size price is designed to extract as much consumer surplus as possible. As such, the implicit unit price may vary across different units.

$$\text{Tax-pooling-payoffs} \begin{cases} \pi^{***2} = (1-\tau_v)[\theta_L u(q^{***2}) - \psi \cdot q^{***2}] \\ U_L^{***2} = 0 \\ U_H^{***2} = (\theta_H - \theta_L) u(q^{***2}) \end{cases} \tag{13}$$

Armed with this characterization we are now able to compare expected profits from the separating and pooling strategies. The seller's decision depends on the distribution of types. The model suggests that separation of types continues to be preferred.

Claim 1. *The separating strategy is more profitable than the pooling scheme if and only if* $\beta \geq \underline{\beta}_O = \frac{(\theta_H-\theta_L)u(q_L^{***1})+\theta_L u(q^{***2})-\psi q^{***2}-[\theta_H u(q_H^{***1})-\psi q_H^{***1}]}{\theta_H u(q_L^{***1})-\psi q_L^{***1}-[\theta_H u(q_H^{***1})-\psi q_H^{***1}]}$

All proofs are in the appendix. The above claim pins down the minimum threshold ($\underline{\beta}_O$) that β must exceed for the separating strategy to remain more profitable than the one-size-fits-all strategy.

Proposition 1. *Suppose that a tax regime* (τ_s, τ_v) *comes into effect. Then,* $\underline{\beta}_O$ *decreases. This increases the range of* β *for which the separating strategy is more profitable than the pooling scheme.*

The model suggests that a tax makes it *less* likely that the seller will switch from a separating strategy to a pooling scheme. Intuitively, the single option has to be priced reasonably low to ensure that the L-type participates. This strategy is not likely to be followed because, in essence, to serve the L-type, the seller must sacrifice a large fraction of the profit contributions earned per package sold. The key point is that, according to the model, if the retailer chooses the separating strategy pre-tax, then the profit-maximizer retailer will not be likely to switch to a pooling pricing scheme post-tax.

Exclusive Strategy with Taxation

We now explore whether, according to the model, the seller will change her segmentation strategy to a single-option scheme excluding the L-type. To serve the H-type exclusively, $FOC[q_L]$ in 7 needs not to bind with equality. Using $FOC[q_H]$ from 6, pricing rule $p_H = \theta_H u(q_H) - (\theta_H - \theta_L)u(q_L)$, and the normalizing assumption $u(0) = 0$, we obtain:

$$\text{Tax-exclusive-quantity} \begin{cases} \theta_H u'(q^{***3}) = \psi \end{cases} \tag{14}$$

L-type buyers drop out of the market because they would earn negative surplus given the price. H-types are held at their reservation value. Expected earnings are:

$$\text{Tax-exclusive-payoffs} \begin{cases} \pi^{***3} = (1-\tau_v)(1-\beta)[\theta_H v(q^{***3}) - \psi q^{***3}] \\ \\ U_i^{***3} = 0 \ \text{ for } i = H,\, L \end{cases} \tag{15}$$

Whether the seller moves to an exclusive scheme depends on β, the probability of a given buyer being an L-type.

Claim 2. *The separating pricing strategy is more profitable than excluding the L-type buyer to serve the H-type if and only if* $\beta \geq \underline{\beta}_E = \frac{(\theta_H - \theta_L)u(q_L^{***1})}{\theta_H u(q_L^{***1}) - c q_L^{***1})}$

The above claim pins down a threshold ($\underline{\beta}_E$) that β must exceed for the separating strategy to be more profitable than an exclusive scheme. As mentioned in proposition 2, the model suggests that the seller is more likely to adopt an exclusive segmentation strategy following the implementation of a tax.

Proposition 2. *Assume that a tax regime* $(\tau_s,\, \tau_v)$ *comes into effect. Then,* $\underline{\beta}_E$ *increases. This reduces the range of* β *for which the separating strategy is more profitable than serving*

H-types exclusively.

Because a tax reduces the range of β for which the separating strategy is more profitable than the H-exclusive scheme, it increases the possibility that retailers might endogenously switch to the H-exclusive strategy.

3.4 Hypotheses

Before discussing our experimental design, in this subsection we proceed to organize the specific hypotheses that we will bring to the data. Later, we will structure the discussion of the empirical results around these predictions.

In our experimental design, further detailed in a later section, we chose a parametrization that would favor separation of buyer types and full market coverage (i.e. not excluding any type from service). Thus, we anticipate sellers in the laboratory to mostly attempt to segment demand by submitting two-option menus. However, considering the implication of propositions 1 and 2, we expect two-option menus, as a proportion of total submissions, to decrease with an active tax in favor of exclusive offers. We do not have an equivalent expectancy regarding the number of offers submitted under a cap rule.

Hypothesis 1 - Impact on the number of options: *Two-package menus will be more common than single-item offers in all treatments. However, the number of two-alternative offers, as a fraction of total submissions, will decrease in the* Tax *treatment in favor of exclusive offers.*

We anticipate most offers to display two alternatives for sale. Therefore, our predictions regarding impacts on consumption and payoffs derive from taking the theoretical outcomes from the separating equilibria across policy environments. In other words, we take the predicted optimal separating schemes in all three policy treatments and contrast their quantity and payoffs outcomes.

Hypothesis 2 - Effects on consumption and payoffs: *The cap rule will reduce the size of the large package, while the tax will result in smaller portions of both small and large alternatives. Regarding earnings, consumer surplus will be lower only for the H-type in the* Tax *treatment. Expected profit will be lower under both interventions.*

In sum, we expect subjects in our *Tax* treatment to submit exclusive single-package offers more often that sellers in other treatments. In addition and in spite of a significant reduction in portion sizes, we expect L-types to remain unaffected under both interventions and H-type consumer's to be negatively impacted by the tax, but not by the cap.

4 Experimental Design

We recruited participants from the student population of a large American public university. Three cardinal reasons support the choice of university students as our subject pool. First, they follow abstract instructions more precisely relative to field professionals (Cooper et al. 1999; Alatas et al. 2008). Second, university students are relatively more homogeneous than professionals and other populations, this allows the experimenters to exert more control in the laboratory. This makes students an appropriate subject pool when addressing research questions closely tied to theory, as is the case in this project (Cason and Wu, 2019). Finally, student homogeneity is a feature that facilitates statistical estimation. Statistical inference is easier when nuisance variation across treatments stemming from factors irrelevant to the main question is minimized (Cason and Wu, 2019).

Table 1 shows the parameters we use in the experiment. We choose specific values to assess the impacts of reducing the quantity of the large option to about half its original size. Both cap and tax are equivalent in their theoretical impact on the size of the large package. We use a per-unit tax because it is the most common way to regulate consumption, including in the food and soda retail industries.[10] It is to the advantage of the seller to offer a menu with two incentive-compatible packages in all treatments.

[Table 1 about here]

There are three treatments. In our *Baseline*, there is no intervention; in treatment *Cap*, there is a limit on the maximum quantity sellers are allowed to offer per package, and in treatment *Tax*, a per-unit fee is charged to sellers. The experimental interface allows sellers to choose the number of alternatives to offer, from zero to two packages. Similarly, they are free to select specific quantities and prices. This degree of flexibility is an important feature of our study because it allows us to contrast both the frequency with which sellers attempt separation in different treatments, and the impact on payoffs and consumption in a setting where sellers might not implement perfect pricing. Table 2 describes the menus that result in the maximum expected profit.[11]

[Table 2 about here]

The purported objective of caps is to restrict the largest option available with the hope

[10]All localities within the U.S. with a "soda tax" enacted by the end of 2019, levied a per volume excise tax. This form of taxation is prevalent in other jurisdictions as well, for example, Mexico implemented a specific tax of one peso per litter in 2014.

[11]In the appendix, we show an equivalent table describing the best single-package offers possible. All of them would generate less expected profit compared to the best separating schemes.

of diminishing consumption. Translated to our experimental setting, a cap should limit the size of the largest alternative when sellers price discriminate. The quantity limit in *Cap* is set to 17 units, which is close to half the size of the optimal size of large option in the *Baseline* treatment (about 32 units). The per-unit tax in the *Tax* treatment was set at a level such that, in theory, it would cause sellers to reduce the quantity of the large option to 17 units as well.[12]

4.1 Procedures and the Experimental Task

We conducted three sessions per treatment. Each session had twelve participants drawn from a subject pool managed with ORSEE (Greiner, 2015). In total, 108 subjects participated in the experiment. Subjects did not participate in more than one session. The interface was implemented using oTree (Chen et al., 2016).

The structure of all sessions was the same. Subjects were given printed copies of the experimental instructions. After the experimenter read the instructions aloud, subjects answered a pre-experimental quiz to make sure they understood them. There were six non-paying trading periods for subjects to become familiar with the computer interface. Afterwards, there were twelve paying trading rounds. Lastly, the subjects were asked to answer a post-experimental survey.[13]

All human subjects took on the role of a seller and interacted exclusively with their

[12] An alternative design would have been to match the restriction by the portion cap rule to the reduction in size induced by current levels of taxes. If we take soda taxes as our benchmark, current taxes are small, thus the cap needed to equate their effect on portions would have been barely noticeable. Because one of our results is that taxes hurt consumers more than caps, we decided to implement a severe portion cap rule. It is reasonable to deduce that if the impact on consumer surplus is null with a very restrictive cap, it would also be absent in more lenient cases.

[13] Feel free to contact the corresponding author to get copies and examples of the material used throughout the experimental sessions.

assigned computer. A computer program imitated the role of a rational buyer. Earnings for both seller and buyer were denominated in an experimental currency called "points." At the end of the session, total accumulated points earned by the sellers were converted to cash at the rate of 100 points per US dollar. Seller and buyer earned points during paying trading periods. All trading periods went as follows: the seller first decided the number of packages to offer; in a subsequent decision screen, she specified price and quantity for each of the packages to offer; then, the buyer was privately assigned a type and proceeded to purchase the package that maximized his payoff; lastly, the seller was shown a screen displaying quantities and prices submitted, the buyer's purchase decision, period payoffs, and her accumulated earnings in points. For every trading period, the buyer taste parameter was randomly assigned to be θ_L or θ_H with equal probability. The buyer would reject any package resulting in negative surplus. If the buyer was presented with two options resulting in the same non-negative payoff, then the purchase decision is random with both options equally likely. In the event of rejection of the entire menu, no points were earned by both seller and buyer. Similarly, if the seller decides not to offer a package, then seller and buyer earn no points. All of the above was common knowledge.

Subjects had access to an on-screen calculator where they could explore different price-quantity combinations before submitting a final offer. The calculator showed, for a given quantity and price, both buyers' surplus, cost of production, and the profit the seller would earn if the package were purchased. To keep relatively similar final monetary earnings across treatments, sellers in the *Tax* treatment started off the session with a balance of 500 points. Subjects had no starting balance in the other treatments. Average earnings in U.S. dollars, including a \$5.00 participation fee, were \$28.03, \$25.72, and \$23.17 in the *Baseline*, *Cap*, and *Tax* treatments correspondingly.

The buyer's role was automated for two main reasons. First, to eliminate uncertainty regarding the buyer's decision process. The seller can be sure that the buyer does not make mistakes, he is memory-less, and his decisions are not explained by any strategic behavior beyond utility maximization. Second, we exclude the confounding effect of inequity aversion. This is the regularity observed in several economic experiments wherein participants give up some of their own payoff to avoid inequitable outcomes between human players (Fehr and Schmidt, 1999). Thus, conditions are such that the seller can explore with different strategies without worrying about possible interpretations that a human buyer could give to her decisions.[14]

5 Results

Table 3 presents descriptive figures from within treatment outcomes.[15] Subjects submit two-option menus more often than single-package offers across all treatments. The majority of offers contain two packages. To the degree that our subjects' objective is to segment demand, they do so successfully. Most large packages are bought by H-type customers, while small packages are regularly acquired by L-type buyers. These patterns suggest that subjects understood the nature of the task, actively attempted to segment demand, and their offers

[14]The final original database contains 1296 observations. We organized the observations as follows: 1) When the subject submitted two packages, but these had identical prices and quantities, we consider this offer to be a single-option offer. In total, we re-classified 7 offers in this way; 4 from *Baseline*, 1 from *Cap*, and 2 from *Tax*. 2) In 23 trading periods, subjects incurred in losses, that is the cost of the purchased package exceeded its price. The median loss was 2600 points ($26.00 usd). We removed the observations of any subject that incurred in a loss of at least 2600 points. In total, the observations of 5 subjects were removed; 2 from *Baseline*, 2 from *Cap*, and 1 from *Tax*. After trimming these, we are left with 1236 observations.

[15]To classify packages as either small or large, we look at quantities. If a seller offered a menu, the option with larger quantity is assigned to be the large package. If the two options have the same quantity, then the alternative with larger price is assigned to be the large package.

were not aimless and/or arbitrary.

[Table 3 about here]

5.1 Main finding: Impact on the number of options

In table 4, we present the results from logistic regressions estimating the probability of subjects offering two-package menus, and the likelihood of subjects submitting one-item offers that exclude the L-type (H-exclusive offers). An offer is classified as exclusive if it satisfies the H-type's but not the L-type's participation constraint. We observe that subjects are 17% less likely to submit menus in the *Tax* treatment compared to the baseline. Likewise, subjects in the taxed group are 15% more likely to offer H-exclusive packages. The effects are statistically significant.

Result 1 - Impact on the number of alternatives: *In accordance with hypothesis 1, the majority of offers submitted by our subjects are two-option menus. In the* Cap *treatment, subjects are not statistically less likely to offer two alternatives. On the other hand, in the* Tax *group, subjects are statistically less likely to submit two-options menus and more likely to submit H-exclusive offers.*

[Table 4 about here]

One of the arguments usually raised against portion cap rules is that they reduce consumer choice. Our data suggests that sellers offer two options in the *Cap* treatment at, on average, the same frequency compared to the *Baseline*. On the other hand, sellers are less likely to offer menus with two alternatives in the *Tax* group. Thus, beyond the intended reduction in consumption common to both interventions, the tax causes a greater impact on consumer choice set.

5.2 Main finding: Effect on consumption and payoffs

We proceed now to discuss the observed impact on quantities and earnings (per-period consumer surplus, expected profit, and total surplus). Table 5 displays the estimated impacts on portions purchased, expected profit, consumer, and total surplus.[16]

[Table 5 about here]

Result 2 - Impact on quantities and payoffs: *In accordance with hypothesis 2, the average purchased quantity of the large alternative is smaller in both regulated treatments. Unlike what we expected, the size of the small serving size is smaller, not only in the* Tax *group, but in the* Cap *treatment as well. Regarding payoffs, consumer surplus and profits are affected as anticipated. Surplus earned by the L-type is unaffected, while the H-type is only affected by the tax. Expected profit is impacted by both interventions.*

As noted, the observed outcomes largely corroborate the model's predictions. Particularly salient is the finding regarding impacts on consumer surplus. Only in the *Tax* treatment we observe an impact, and exclusively on H-type buyers. No such effect is found in the *Cap* group. This outcome runs against the common (and intuitive) claim that caps are particularly harmful to consumers.

Together, result 1 and the finding that consumers are only affected in the *Tax* treatment provide empirical evidence to cast doubt on the common impression that limits on quantity

[16] Total surplus is the sum of profit, consumers surplus, and tax revenue (quantity times tax fee).

necessarily hurt consumers more than specific taxation. In fact, we find that, in settings where sellers have an incentive to price discriminate among discrete buyer types, taxes may be worse than caps if we take choice sets and consumer surplus as metrics for evaluation.

Table 5 shows outcomes from econometric models that allow the segmentation strategy (separating, pooling, and exclusive) to vary. For completeness, in the appendix we show similar econometric estimates holding the segmentation scheme constant. The main effect regarding consumer surplus remains when looking at separating and pooling offers. With exclusive submissions, however, neither interventions impact consumer payoffs. This is because exclusive strategies hold the H-type buyer at his reservation value across policy treatment.

6 Conclusion

We report an experiment where single-product sellers serve two buyers with private preferences. We manipulate the policy environment across treatments to compare the effects of portion cap rules and taxes, paying particular attention to the number of alternatives and consumer surplus. Caps and taxes have been proposed as alternatives to restrict the consumption of foods judged to have deleterious effects on human health, particularly sugary drinks. Opponents to caps often argue that they are particularly harmful to consumers and reduce choice. Instead, taxes are commonly favored. In the setting we study, we find the accusations to be misplaced. Compared to the regulation-free baseline, sellers in the taxed treatment submit two-option menus less often and their pricing is such that consumers suffer welfare losses. These effects are absent in the treatment where a cap rule is enforced.

To the best of our knowledge, ours is the first study that makes a formal comparison of both types of regulations and can offer insights about potential losers from each restriction. We remain agnostic with respect to the effectiveness of either measure to successfully combat obesity. However, results from our study suggest that if caps are to be dismissed as a regulatory alternative in favor of specific taxation, reasons beyond alleged impacts on choice set and consumer surplus ought to be put forward; at least in settings where sellers separate demand in discrete segments.

Potential limitations of our work provide opportunities to future researchers to expand the analysis. Our study stems from a partial equilibrium model without significant market failures. This restricts the extent to which the outcomes can be applied to normative questions regarding whether governmental intervention is granted on grounds of social welfare.

Because we rely on a laboratory experiment, the external validity of our experiment is limited. However, by abstracting away from institutional details, the experiment allows us to concentrate on the question at hand: how do caps and taxes compare in a setting characterized by adverse selection. Future studies can gradually incorporate specific attributes found in the field. Researchers interested in particular markets can conduct studies that incorporate particular considerations and institutional details relevant to specific applications.

Behavioral theories of consumer choice and psychological theories of food consumption do not inform our design. We compare the impacts of the regulation relying on utility theory and a classical definition of consumer surplus. As the first empirical study contrasting taxes and caps in a market with heterogeneous buyers, this is beneficial rather than detrimental, to our work. We provide an early study based on orthodox assumptions and principles. This can serve as a baseline foundation for researchers interested in extending the design to better fit the particular needs of their field of interest.

Tables

Table 1: Parameter values used in the experiment

Variable	Value	Description
β	0.5	Probability of the buyer being a low type.
p	$[0, 1, \ldots, 25000]$	range of possible prices.
q	$[0, 1, \ldots, 90]$	range of possible quantities.
c	240	Unitary cost of production.
$v(q)$	$q^{0.95}$	Buyer's unscaled utility of consumption.
θ_H	300	High-type buyer's taste parameter.
θ_L	290	Low-type buyer's taste parameter.
$\hat{q}$	17	Maximum size allowed under portion cap rule.
t_s	7.35	Per-unit fee active under taxation.

Table 2: Description of menus that maximize seller's expected profit

Variable	Treatment	Mean	Min	Max
Large quantity	Baseline	30.71	30.00	32.00
	Cap	17.00	17.00	17.00
	Tax	17.00	17.00	17.00
Large price	Baseline	7690.71	7511.00	7768.00
	Cap	4353.33	4345.00	4362.00
	Tax	4362.00	4362.00	4362.00
Small quantity	Baseline	8.00	7.00	9.00
	Cap	8.00	7.00	9.00
	Tax	7.00	7.00	7.00
Small Price	Baseline	2089.71	1841.00	2338.00
	Cap	2089.67	1841.00	2338.00
	Tax	1841.00	1841.00	1841.00
U_H	Baseline	73.35	64.53	81.76
	Cap	73.04	64.37	81.37
	Tax	64.37	64.37	64.37
U_L	Baseline	0.74	0.45	0.90
	Cap	0.72	0.45	0.90
	Tax	0.79	0.79	0.79
$\mathbb{E}[\pi]$	Baseline	244.50	244.50	244.50
	Cap	221.50	221.50	221.50
	Tax	133.30	133.30	133.30

Because subjects can choose only integer numbers, there are 7 menus that could maximize expected profit when separating types in the *Baseline* group. In *Cap*, there are 3 menus that would maximize expected profit. In *Tax*, there is 1 menu that would maximize expected profit.

Table 3: Submitted offers and consumption decisions by buyer type

	Baseline		Cap		Tax	
	Menu	Single	Menu	Single	Menu	Single
Offers submitted:						
# Obs/Total (%)	277/408 (67.9)	131/408 (32.1)	254/408 (62.2)*	154/408 (37.7)	221/420 (52.6)***	197/420 (46.9)
Mean large quantity	29.685	21.305	14.956***	14.402***	19.131***	12.781***
Mean large price	7379.407	5341.167	4155.440***	4334.551***	4990.936***	3464.604***
Mean small quantity	14.104		10.771***		9.986***	
Mean small price	3587.909		3007.763***		2895.280***	
High type:						
Buy large offer	223/277 (80.5)	130/131(99.2)	190/254 (74.8)	138/154 (89.6)***	125/221 (56.6)***	185/197 (93.9)***
Buy small offer	51/277 (18.4)		56/254 (22.1)		83/221 (37.6)	
Reject	3/277 (1.1)	1/131 (0.8)	8/254 (3.1)*	16/154 (10.4)***	13/221 (5.9)***	12/197 (6.1)**
Mean consumed quantity	26.350	21.430	14.536***	15.260***	13.418***	11.367***
Mean paid price	6536.372	5370.715	3662.528***	3853.775***	3414.701***	2942.037***
Low type:						
Buy large offer	26/277 (9.4)	90/131 (68.7)	88/254 (34.6)***	115/154 (74.7)	13/221 (5.9)***	97/197 (49.2)***
Buy small offer	215/277 (77.6)		143/254 (56.3)***		157/221 (71.0)*	
Reject	36/277 (13.0)	41/131 (31.3)	23/254 (9.1)	39/154 (25.3)	51/221 (23.1)***	100/197 (50.8)***
Mean consumed quantity	14.286	16.866	12.545***	15.147	8.882***	8.226***
Mean paid price	3594.958	4215.077	3166.844***	3814.478	2268.500***	2132.958***

The stars indicate whether there are significant difference (* at the 10%, ** at the 5%, and *** at the 1%) between the relevant treatment and the baseline. Differences between ratios tested with χ^2 independence tests. Differences between averages of quantities and prices tested with Mann-Whitney tests.

Table 4: Probability of submitting two-package and exclusive offers

Dependent variable:	Two-options menu		H-exclusive offer	
	Model	Marginal effect	Model	Marginal effect
Cap	-1.116	-0.078	1.009	0.005
	(0.760)	(0.063)	(0.998)	(0.049)
Tax	-2.071**	-0.170*	2.820***	0.150***
	(0.893)	(0.087)	(0.798)	(0.051)
Period	-0.086*	-0.005***	0.080	-0.000
	(0.047)	(0.002)	(0.052)	(0.002)
Cap*Period	0.043		-0.144***	
	(0.055)		(0.054)	
Tax*Period	0.045		-0.105	
	(0.065)		(0.099)	
Constant	2.748***		-5.008***	
	(0.798)		(0.688)	
N	1236	1236	1236	1236

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Robust standard errors clustered at the session level in parentheses. Marginal effects: standard errors estimated with delta method in parentheses.

Table 5: Impacts of the regulations on quantity and per-period payoffs

	Dependent variable					
	q_H	q_L	$\mathbb{E}[\pi]$	U_H	U_L	Total Surplus
Cap	-9.507***	-2.759***	-33.305*	-2.662	20.536	-39.089*
	(0.940)	(0.725)	(19.567)	(17.457)	(14.688)	(20.156)
Tax	-11.67***	-6.443***	-93.562***	-67.864***	-2.751	-44.378**
	(1.152)	(0.894)	(13.244)	(10.994)	(7.266)	(17.781)
Period	0.210***	-0.029	1.612***	-1.397	-0.201	1.727***
	(0.039)	(0.023)	(0.212)	(0.931)	(0.274)	(0.261)
Cap*Period	-0.106**	0.120***	1.901	-0.420	-2.560	1.894
	(0.052)	(0.025)	(2.048)	(2.020)	(1.790)	(2.055)
Tax*Period	-0.056	0.040	-0.506*	0.625	-0.175	0.104
	(0.086)	(0.054)	(0.294)	(1.414)	(0.404)	(0.652)
Constant	23.418***	15.328***	164.545***	149.834***	19.634***	182.267
	(0.637)	(0.523)	(11.550)	(2.917)	(4.363)	(12.499)
N	1181	944	1236	1236	1236	1236

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Robust standard errors clustered at the session level in parentheses. Marginal effects: standard errors estimated with delta method in parentheses.

References

Aguilar-Esteva, A., Gutierrez, E., and Seira, E. (2019). The Effectiveness of Sin Food Taxes: Evidence from Mexico. *SSRN Electronic Journal*.

Ahn, S. and Lusk, J. L. (2021). Non-Pecuniary Effects of Sugar-Sweetened Beverage Policies. *American Journal of Agricultural Economics*, 103(1):53–69.

Alatas, V., Cameron, L., Chaudhuri, A., Erkal, N., and Gangadharan, L. (2008). Subject pool effects in a corruption experiment: A comparison of Indonesian public servants and Indonesian students. *Experimental Economics*, 12(1):113–132.

Amrstong, M., Cowan, S., and Vickers, J. (1995). Nonlinear pricing and price cap regulation. *Journal of Public Economics*, 58(1):33–55.

Arteaga, J. C., Flores, D., and Luna, E. (2021). The effect of a soft drink tax in mexico: evidence from time-series industry data. *Australian Journal of Agricultural and Resource Economics*, 65(2):349–366.

Besanko, D., Donnenfeld, S., and White, L. J. (1988). The multiproduct firm, quality choice, and regulation. *The Journal of Industrial Economics*, 36(4):411.

Bonnet, C. and Réquillart, V. (2013). Tax incidence with strategic firms in the soft drink market. *Journal of Public Economics*, 106:77–88.

Bourquard, B. A. and Wu, S. Y. (2020). An analysis of beverage size restrictions. *American Journal of Agricultural Economics*, 102(1):169–185.

Cason, T. N. and Wu, S. Y. (2019). Subject Pools and Deception in Agricultural and Resource Economics Experiments. *Environmental and Resource Economics*, 73(3):743–758.

Chen, D. L., Schonger, M., and Wickens, C. (2016). oTree-An open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance*, 9:88–97.

Chu, C. S., Leslie, P., and Sorensen, A. (2011). Bundle-Size Pricing as an Approximation to Mixed Bundling. *American Economic Review*, 101(1):263–303.

Colchero, M. A., Rivera-Dommarco, J., Popkin, B. M., and Ng, S. W. (2017). In mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. *Health Affairs*, 36(3):564–571.

Cooper, D. J., Kagel, J. H., Lo, W., and Gu, Q. L. (1999). Gaming Against Managers in Incentive Systems: Experimental Results with Chinese Students and Chinese Managers. *American Economic Review*, 89(4):781–804.

Corts, K. S. (1995). Regulation of a multi-product monopolist: Effects on pricing and bundling. *The Journal of Industrial Economics*, 43(4):377.

Fehr, E. and Schmidt, K. M. (1999). A Theory of Fairness, Competition, and Cooperation. *The Quarterly Journal of Economics*, 114(3):817–868.

Fletcher, J. M., Frisvold, D., and Tefft, N. (2010a). Can soft drink taxes reduce population weight? *Contemporary Economic Policy*, 28(1):23–35.

Fletcher, J. M., Frisvold, D. E., and Tefft, N. (2010b). The effects of soft drink taxes on child and adolescent consumption and weight outcomes. *Journal of Public Economics*, 94(11-12):967–974.

Fletcher, J. M., Frisvold, D. E., and Tefft, N. (2014). Non-linear effects of soda taxes on consumption and weight outcomes. *Health Economics*, 24(5):566–582.

Flood, J. E., Roe, L. S., and Rolls, B. J. (2006). The Effect of Increased Beverage Portion Size on Energy Intake at a Meal. *Journal of the American Dietetic Association*, 106(12):1984–1990.

Greiner, B. (2015). Subject pool recruitment procedures: organizing experiments with ORSEE. *Journal of the Economic Science Association*, 1(1):114–125.

Grogger, J. (2017). Soda taxes and the prices of sodas and other drinks: Evidence from Mexico. *American Journal of Agricultural Economics*, 99(2):481.

Grynbaum, M. M. (2012). Soda Makers Begin Their Push Against New York Ban - The New York Times. Retrieved from http://www.nytimes.com.

Grynbaum, M. M. and Connelly, M. (2012). 60 in City Oppose Bloomberg's Soda Ban, Poll Finds. Retrieved from http://www.nytimes.com.

Hendel, I. and Nevo, A. (2013). Intertemporal price discrimination in storable goods markets. *American Economic Review*, 103(7):2722–2751.

Holton, R. H. (1957). Price discrimination at retail: The supermarket case. *The Journal of Industrial Economics*, 6(1):13.

Hoppe, E. I. and Schmitz, P. W. (2015). Do sellers offer menus of contracts to separate buyer types? an experimental test of adverse selection theory. *Games and Economic Behavior*, 89:17–33.

Hoppe, E. I. and Schmitz, P. W. (2018). Hidden action and outcome contractibility: An experimental test of moral hazard theory. *Games and Economic Behavior*, 109:544–564.

Huck, S., Seltzer, A. J., and Wallace, B. (2011). Deferred Compensation in Multiperiod Labor Contracts: An Experimental Test of Lazear's Model. *American Economic Review*, 101(2):819–843.

Jensen, S. and Schjelderup, G. (2011). Indirect taxation and tax incidence under nonlinear pricing. *International Tax and Public Finance*, 18(5):519–532.

John, L. K., Donnelly, G. E., and Roberto, C. A. (2017). Psychologically informed implementations of sugary-drink portion limits. *Psychological Science*, 28(5):620–629.

Ledikwe, J. H., Ello-Martin, J. A., and Rolls, B. J. (2005). Portion Sizes and the Obesity Epidemic. *The Journal of Nutrition*, 135(4):905–909.

Maskin, E. and Riley, J. (1984). Monopoly with Incomplete Information. *The RAND Journal of Economics*, 15(2):171.

McManus, B. (2007). Nonlinear pricing in an oligopoly market: the case of specialty coffee. *The RAND Journal of Economics*, 38(2):512–532.

Mussa, M. and Rosen, S. (1978). Monopoly and product quality. *Journal of Economic Theory*, 18(2):301–317.

Myerson, R. B. (1979). Incentive Compatibility and the Bargaining Problem. *Econometrica*, 47(1):61.

Nuno-Ledesma, J. G. (2021). An Analysis of Portion Cap Rules with a Multiproduct Seller. *American Journal of Agricultural Economics*.

Rolls, B. J., Roe, L. S., and Meengs, J. S. (2006). Larger Portion Sizes Lead to a Sustained Increase in Energy Intake Over 2 Days. *Journal of the American Dietetic Association*, 106(4):543–549.

Sappington, D. E. M. and Sibley, D. S. (1992). Strategic nonlinear pricing under price-cap regulation. *The RAND Journal of Economics*, 23(1):1.

Silver, L. D., Ng, S. W., Ryan-Ibarra, S., Taillie, L. S., Induni, M., Miles, D. R., Poti, J. M., and Popkin, B. M. (2017). Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in berkeley, california, US: A before-and-after study. *PLoS Medicine*, 14(4):e1002283.

Sturm, R., Powell, L. M., Chriqui, J. F., and Chaloupka, F. J. (2010). Soda taxes, soft drink consumption, and children's body mass index. *Health Affairs*, 29(5):1052–1058.

Wilson, B. M., Stolarz-Fantino, S., and Fantino, E. (2013). Regulating the Way to Obesity: Unintended Consequences of Limiting Sugary Drink Sizes. *PLoS ONE*, 8(4):e61081.

Young, L. R. and Nestle, M. (2002). The Contribution of Expanding Portion Sizes to the US Obesity Epidemic. *American Journal of Public Health*, 92(2):246–249.

Appendix for online publication

Proof of Claim 1

Proof. We will show that $\mathbb{E}[\pi^{***1}] \geq \mathbb{E}[\pi^{***2}]$ is equivalent to

$\beta \geq \underline{\beta}_O = \frac{[\theta_H - \theta_L]u(q_L^{***1}) + \theta_L u(q^{***2}) - \psi q^{***2} - [\theta_H u(q_H^{***1}) - \psi q_H^{***1}]}{\theta_H u(q_L^{***1}) - \psi q_L^{***1} - [\theta_H u(q_H^{***1}) - \psi q_H^{***1}]}$. .

Using the profit expressions under the taxed separating and one-size-fits-all strategies, note that $\pi^{***1} \geq \pi^{***2}$ can be expressed as

$(1-\tau_v)\Big\{(\beta)[\theta_L u(q_L^{***1}) - \psi q_L^{***1}] + (1-\beta)\big\{[\theta_H u(q_H^{***1}) - (\theta_H - \theta_L)u(q_L^{***1})] - \psi q_H^{***1}\big\}$

$\geq (1-\tau_v)[\theta_L u(q^{***2}) - \psi q^{***2}]$

Solving for β yields $\beta \geq \frac{[\theta_H - \theta_L]u(q_L^{***1}) + \theta_L u(q^{***2}) - \psi q^{***2} - [\theta_H u(q_H^{***1}) - \psi q_H^{***1}]}{\theta_H u(q_L^{***1}) - \psi q_L^{***1} - [\theta_H u(q_H^{***1}) - \psi q_H^{***1}]} = \underline{\beta}_O$ □

Proof of Proposition 1

Proof. Recall that $\psi \equiv \frac{d\Psi_i}{dq_i} = (\tau_s + c) \div (1-\tau_v)$. The no taxation case is nested within ψ when $\tau_s = \tau_v = 0$. When there is no tax, $\psi = c$ but if either τ_s or $\tau_v > 0$, then $\psi > c$. Thus, taxation effectively increases marginal cost.

By Claim 1, $\frac{[\theta_H - \theta_L]u(q_L^{***1}) + \theta_L u(q^{***2}) - \psi q^{***2} - [\theta_H u(q_H^{***1}) - \psi q_H^{***1}]}{\theta_H u(q_L^{***1}) - \psi q_L^{***1} - [\theta_H u(q_H^{***1}) - \psi q_H^{***1}]} = \underline{\beta}_O$.

Applying the quotient rule, we have $\frac{\partial \underline{\beta}_O}{\partial \psi} = \frac{q_L^{***1} - q^{***2}}{\theta_H u(q_L^{***1}) - \psi q_L^{***1} - [\theta_H v(q_H^{***1}) - \psi q_H^{***1}]}$. Note that the denominator is squared and therefore must be positive. To sign the numerator, comparing the first order conditions characterizing quantities, it is obvious that $q^{***2} > q_L^{***1}$. Hence, $\frac{\partial \underline{\beta}_O}{\partial \psi} < 0$. □

Proof of Claim 2

Proof. We will show that $\mathbb{E}[\pi^{***1}] \geq \mathbb{E}[\pi^{***3}]$ is equivalent to $\beta \geq \frac{[\theta_H - \theta_L]u(q_L^{***1})}{\theta_H u(q_L^{***1}) - \psi q_L^{***1}} = \underline{\beta}_E$.

Using the profit expressions under the taxed separating and H-exclusive strategies, note that $\pi^{***1} \geq \pi^{***3}$ can be expressed as $(1-\tau_v)\Big\{(\beta)[\theta_L u(q_L^{***1}) - \psi q_L^{***1}] + (1-\beta)\big\{[\theta_H u(q_H^{***1}) - (\theta_H - \theta_L)u(q_L^{***1})] - \psi q_H^{***1}\big\} \geq (1-\tau_v)(1-\beta)[\theta_H u(q^{***3}) - \psi q^{***3}]$. Using the fact that the H-type first order conditions are identical, we have $q_H^{***1} = q^{***3}$. This allows us to simplify the inequality to obtain $\beta[\theta_H u(q_L^{***1}) - \psi q_L^{***1}] \geq [\theta_H - \theta_L]u(q_L^{***1})$. Solving for β yields $\beta \geq \frac{[\theta_H - \theta_L]u(q_L^{***1})}{\theta_H u(q_L^{***1}) - \psi q_L^{***1}}$ □

Proof of Proposition 2

Proof. Recall that $\psi \equiv \frac{d\Psi_i}{dq_i} = (\tau_s + c) \div (1-\tau_v)$. The no taxation case is nested within ψ when $\tau_s = \tau_v = 0$. When there is no tax, $\psi = c$ but if either τ_s or $\tau_v > 0$, then $\psi > c$. Since c is the lower bound of ψ, it follows that any positive tax implies an increase in ψ. One can easily see from $\beta_E = \frac{[\theta_H - \theta_L]u(q_L^{***1})}{\theta_H u(q_L^{***1}) - \psi q_L^{***1}}$ that an increase in ψ implies an increase in β_E. □

What are the effects of taxation holding the pricing strategy constant?

Here we show the work that results in our testable hypotheses. We concentrate first on the impacts of taxation.

Proposition 3. Suppose that a tax regime (τ_s, τ_v) is implemented. Then, serving sizes for both types of consumers decline.

Proof. Suppose that a tax a tax regime (τ_s, τ_v) is implemented. A simple comparison can show that $q_H^{*1} > q_H^{***1}$ and $q_H^{*1} > q^{***3}$. Therefore, regardless of whether the retailer continues with the separating strategy or switches to the H-exclusive strategy, the H-type serving will decline.

Also, $q_L^{*1} > q_L^{***1}$ so the L-type serving size declines if the retailer continuous with the separating strategy post tax. If the retailer switches to the H-exclusive strategy, then by proposition 3, L-type consumers are excluded so that serving size trivially declines to zero. In either case, L-type serving size declines. □

Proposition 4. Suppose that a tax regime (τ_s, τ_v) is implemented. Then consumer surplus for H-types declines. Consumer surplus for L-types is unaffected.

Proof. Suppose that a tax regime (τ_s, τ_v) is implemented. Smaller quantities with regulations imply $U_H^{*1} > U_H^{***3}$. Therefore, the H-type buyer's surplus declines.

Also, the L-type buyer is always held at his reservation utility. Thus, a tax does not affect the L-type's consumer surplus as his utility remains at the reservation both pre and post-tax. □

Intuitively, if a tax does not cause the retailer to switch away from a separating strategy, the tax still causes the L-type serving size to drop, which lowers the H-type information rent. Thus, H-type consumer welfare decreases.

Proposition 5. Suppose that a tax regime (τ_s, τ_v) is implemented. Then, retailer surplus unambiguously declines.

Proof. Suppose that a tax regime (τ_s, τ_v) is implemented. If the retailer continues to use the segmentation strategy post-tax, then by proposition 2, $\pi^{*1} > \pi^{***3}$.

If instead, the retailer switches to a the H-exclusive strategy, then the retailer's post-tax value function is $\pi^{***3} = (1 - \tau_v)(1 - \beta)[\theta_H v(q^{***3}) - \psi q^{***3}]$. Note that if the retailer had adopted a H-exclusive strategy pre-tax, then the retailer's value function would be

$\pi^{*3} = (1-\beta)[\theta_H u(q^{*3}) - \psi q^{*3}]$ where q^{*3} is the optimal H-type serving size in the absence of a tax. This would be determined by the first order condition $\theta_H u'(q^{*3}) = c$. However, note that Taxed Case Exclusive that the same condition for the post-tax H-exclusive strategy is $\theta_H u'(q^{***3}) = \psi$. Because $\psi > c$, it follows that $q^{***3} < q^{*3}$ and therefore $\pi^{*3} > \pi^{***3}$. However, we know that, by assumption, the retailer adopts a separating strategy pre-tax so it must be the case that $\pi^{*1} > \pi^{*3}$. Hence, by transitivity, $\pi^{*1} > \pi^{***3}$. $\square$

Proposition 6. *Assume that the government enforces a tax regime (τ_s, τ_v) with at least one type of tax strictly positive. Suppose that the retailer decides to offer one single cup size designed to serve H-type buyers solely. Then:*

1. $\theta_H u'(q^{***3}) = \psi > c$. *There is a tax induced reduction in q^{***3} below first best. Thus, $q^{***3} < q_H^{*1}$*

2. *L-type buyers are excluded and do not engage in trade.*

3. *The serving price is $p^{***3} = \theta_H v(q^{***3})$ which does not include an information rent.*

4. *Expected profit is lower.*

5. *Both buyer types are held at their reservation values; i.e. $U_H = U_L = 0$.*

The proof is just a straightforward comparison so we exclude it.

Proposition 7. *Assume the government enforces a tax regime (τ_s, τ_v) with at least one type of tax strictly positive. If the retailer decides not to screen the market and offers a one-size-fits-all package designed to serve both types of buyers, then:*

1. *$\theta_L u'(q_L^{***2}) = \psi$ so that buyers are provided with a quantity, q_L^{***2}, that is smaller than the L-type first best.*

2. *The price per serving is $p^{***2} = \theta_L u(q^{***2})$.*

3. *The seller's value function is reduced.*

4. *The L-type consumer value function is $U_L^{***2} = 0$.*

5. *The H-type consumer value function is $U_H^{***2} = (\theta_H - \theta_L)u(q^{***2}) > 0$.*

The proof is straightforward and therefore excluded. Note that H-type buyers still earn excess rents though this is not due to screening driven information rents.

What are the effects of the size cap holding the pricing strategy constant?

We present the work that results in the comparison between cap rule and the baseline just for completeness. For more details and a longer exposition, we direct the reader to Bourquard and Wu (2020).

Consider the set of possible discrete pricing strategies:

- Case ib: Sell to both types of consumers with a menu of differentiated H-type and L-type price-size options.

- Case iib: Sell exclusively to H-types.

- Case iiib: Sell to all types using one-size-fits-all pricing.

Case ib: Sell to both types with a menu of H-type and L-type options.

Assuming that the size-restriction only caps the H-type serving so that the restriction has an upper corner solution, $0 \leq q_H \leq \hat{q}$, then the K-T conditions are

$$\theta_H u'(q_H) \geq c \quad where \quad q_H = \hat{q} \tag{16}$$

$$\beta\left[\theta_L u'(q_L) - c\right] + (1-\beta)\left[-(\theta_H - \theta_L)u'(q_L)\right] \leq 0 \quad where \quad q_L \geq 0 \quad \& \quad \frac{\partial \pi}{\partial q_L} q_L = 0 \tag{17}$$

These conditions imply that $q_H = \hat{q}$ and $\theta_L u'(q_L) = c + \frac{(1-\beta)}{\beta}\left[\theta_H - \theta_L\right] u'(q_L)$. But the latter is identical to the unregulated case. so that a beverage size-restriction would have no impact on q_L if the separating strategy is used post-regulation.

Furthermore, because $\tilde{q}_L$ is unchanged, and q_H^* decreases to $\hat{q}$, this suggests that p_H drops but p_L remains the same.

Lemma 1 - Suppose that there is a size-restriction $q_H \leq \hat{q}$ such that the retailer continues to use a separating pricing strategy where $0 < q_L < q_H = \hat{q}$. Then

1. The H-type's serving size declines to $q_H = \hat{q} < q_H^*$ and p_H drops from $t_H = \theta_H u(q_H^*) - (\theta_H - \theta_L)u(\tilde{q}_L) - \overline{u}$ to $\hat{t}_H = \theta_H u(\hat{q}) - (\theta_H - \theta_L)u(\tilde{q}_L) - \overline{u}$,

2. The L-type's serving size, $\tilde{q}_L$, and price, p_L, remain unchanged.

3. The retailer's profit declines to: $\Pi_{ib} = \beta\left[\theta_L u(\tilde{q}_L) - c\tilde{q}_L - \overline{u}\right] +$

   $(1-\beta)\left[\theta_H u(\hat{q}) - c\hat{q} - (\theta_H - \theta_L)u(\tilde{q}_L) - \overline{u}\right]$

4. The H-type's welfare (utility) remains unchanged at $U_{Hib} = \overline{u} + [\theta_H - \theta_L]u(\tilde{q}_L)$ (earns information rents).

5. The L-type's welfare remains unchanged at $U_{Lib} = \overline{u}$ (earns no excess surplus).

Proof of Lemma 1

Proof. The proof for part (1) follows from the binding size-restriction, which yields K-T condition 16 and thus, $q_H = \hat{q}$. Also, p_H drops because q_H^* is replaced with the smaller $\hat{q}$ in the the optimal price function. Since the price function is a function of $p(q_H)$ and $p(q_H)$ is increasing in $q_H \; \forall \; q_H < q_H^*$, it must be true that the new price $\hat{t}_H < t_H$ since $\hat{q} < q_H^*$.

Part (2) follows from the first order condition for q_L (17), which is unchanged from the unregulated case. Hence, the retailer will still offer the same $\tilde{q}_L$ as the unregulated case. Serving price p_L is unchanged because the L-type price is a function of only q_L (and not q_H).

The proofs for parts (3), (4), and (5) are easy to show by substituting the optimal prices and quantities into the objective functions of the retailers and consumers. □

Case iib: Sell to only high types with $q_L = 0$

Here, the seller only serves H-type consumers because it is too costly in terms of information rents to also serve L-types. Neither 16 nor 17 hold with strict equality so $q_H^* = \hat{q}$ and $\tilde{q}_L = 0$. Because the size-restriction causes q_H^* to drop to $\hat{q}$, $p_H^* = \theta_H u(q_H^*) - \overline{u}$ (from case ii) drops to $\hat{p}_H = \theta_H u(\hat{q}) - \overline{u}$.

Lemma 2 - Suppose that there is a regulatory restriction of the form $q_H \leq \hat{q}$ and the retailer serves only H-type consumers. Then

1. The H-type's serving size declines to $q_H = \hat{q} < q_H^*$ and p_H drops from $p_H^* = \theta_H u(q_H^*) - \overline{u}$ to $\hat{p}_H = \theta_H u(\hat{q}) - \overline{u}$.

2. The retailer's profit declines to: $\Pi_{iib} = (1 - \beta)[\theta_H u(\hat{q}) - c\hat{q} - \overline{u}]$

3. The H-type's consumer welfare is: $U_{Hiib} = \overline{u}$ (no excess rents).

Proof of Lemma 2

Proof. Part (1) follows from the assumption of a binding restriction, $\hat{q}$, which yields K-T condition 16 so $q_H = \hat{q}$. The serving price, p_H, drops because q_H^* is replaced with the smaller $\hat{q}$ in the the optimal price function. Since the price function is a function of $u(q_H)$ and $u(q_H)$ is increasing in q_H $\forall$ $q_H < q_H^*$, it follow that $\hat{p}_H < p_H$ since $\hat{q} < q_H^*$.

The proofs for parts (2) and (3) follow from substituting the optimal prices and quantities into the objective functions for the retailer and consumers. $\square$

Case iiib: Sell to both types with a one-sized fits all package

The optimal one-size-fits-all strategy under a size restriction is generated by solving:

$$\max_{p,q} [p - cq] \quad s.t. \tag{18}$$

$$\theta_L u(q) - p \geq \overline{u} \tag{19}$$

$$0 \leq q \leq \hat{q} \tag{20}$$

Because $\theta_L < \theta_H$, the H-type participation constraint is always satisfied so long as L-type constraint is satisfied. The binding participation constraint 19 can be substituted into the objective function to get:

$$\max_{q}] [\theta_L u(q) - cq - \overline{u}] \tag{21}$$

$$0 \leq q \leq \hat{q} \tag{22}$$

which yields the Kuhn-Tucker conditions:

$$\theta_L u'(q) \geq c \quad \& \quad q \leq \hat{q} \quad \& \quad \frac{\partial \pi}{\partial q}(\hat{q} - q) = 0 \tag{23}$$

Solving the K-T conditions yields the following proposition.

Lemma 3 - Suppose that there is a restriction of the form $q \leq \hat{q}$ and the retailer uses a one-size-fits-all strategy for both types of consumers. Then

1. The quantity offered to both types of consumers is $q = min\{q_L^*, \hat{q}\}$ where q_L^* is the first-best quantity for the L-type consumer.

2. The price is $p = \theta_L u(q) - \overline{u}$.

3. The retailer's profit is: $\Pi_{iiib} = \theta_L u(q) - cq - \overline{u}$.

4. The H-type's consumer welfare is: $U_{Hiiib} = \overline{u} + [\theta_H - \theta_L]u(\hat{q})$ (excess rents).

5. The L-type's consumer welfare is: $U_{Liiib} = \overline{u}$ (no excess rents).

Proof of Lemma 3

Proof. Part (1) follows from K-T condition 23. That is, if the size-constraint is not binding so that $q < \hat{q}$, then the first order is $\theta_L u'(q) = c'(q)$ so the solution to 23 is clearly equal to the first best level of quantity for L-types, q_L^*. If the size constraint is binding, then, $\hat{q} \leq q_L^*$ in which case $q = \hat{q}$. Hence, $q = min\{q_L^*, \hat{q}\}$

Part (2) follows easily from the optimal q and the binding participation constraint.

Parts (3)-(5) follow from substituting the optimal q and t into the objective functions of the retailer, and consumers. □

Impacts on consumption and payoffs holding segmentation strategy constant

The hypotheses regarding effects with separating schema are detailed in the main text. Here, we first present the hypotheses when sellers adopt single-packages strategies.

Hypothesis 3 - Effects when subjects pool demand: *When sellers pool demand with "one-size-fits-all" offers, the quantity of the package is smaller only in the* Tax *treatment, and remains unchanged with a cap rule. Consumer surplus earned by the H-type is reduced only in the* Tax *treatment. The L-type is not impacted by either intervention. Expected profit is lower under both regulations.*

Hypothesis 4 - Effects when subjects exclude the L-type buyer: *When subjects submit offers to serve H-types exclusively, the quantity of the only package will be smaller in both* Cap *and* Tax *treatments, compared to the baseline. Regarding payoffs, the H-type is not affected by either intervention. Expected profit is lower with both regulations.*

Description of menus that maximize seller's expected profit given a single-package strategy

Variable	Treatment	Pooling			Exclusive		
		Mean	Min	Max	Mean	Min	Max
Large quantity	Baseline				31.50	30.00	33.00
	Cap				17.00	17.00	17.00
	Tax				17.00	17.00	17.00
Large price	Baseline				7952.00	7832.00	8312.00
	Cap				4426.00	4426.00	4426.00
	Tax				4426.00	4426.00	4426.00
Small quantity	Baseline	15.50	15.00	16.00			
	Cap	15.50	15.00	16.00			
	Tax	9.00	9.00	9.00			
Small Price	Baseline	3919.00	3799.00	4039.00			
	Cap	3919.00	3799.00	4039.00			
	Tax	2338.00	2338.00	2338.00			
U_H	Baseline	135.39	131.14	139.64	0.49	0.08	0.76
	Cap	135.39	131.14	139.64	0.37	0.37	0.37
	Tax	81.09	81.09	81.09	0.37	0.37	0.37
U_L	Baseline	0.24	0.13	0.35	0.00	0.00	0.00
	Cap	0.24	0.13	0.35	0.00	0.00	0.00
	Tax	0.45	0.45	0.45	0.00	0.00	0.00
$\mathbb{E}[\pi]$	Baseline	199.00	199.00	199.00	196.00	196.00	196.00
	Cap	199.00	199.00	199.00	173.00	173.00	173.00
	Tax	111.85	111.85	111.85	110.53	110.53	110.53

In *Baseline*, 2 offers could achieve the maximum payoff conditional on implementing a pooling scheme; 4 offers could reach the maximum payoff conditional on adopting an exclusive strategy. In *Cap*, 2 offers could achieve the maximum payoff conditional on implementing a pooling scheme; 1 offer could reach the maximum payoff conditional on adopting an exclusive strategy. In *Tax*, 1 offer could achieve the maximum payoff conditional on implementing a pooling scheme; 1 offer could reach the maximum payoff conditional on adopting an exclusive strategy.

Impacts of the regulations on quantity and per-period payoffs - Two-package menus only

	Dependent variable					
	q_H	q_L	$\mathbb{E}[\pi]$	U_H	U_L	Total Surplus
Cap	-9.366***	-2.657***	-38.521	3.238	30.548	-44.294*
	(1.259)	(0.678)	(26.110)	(32.294)	(26.293)	(25.660)
Tax	-11.119***	-5.790***	-97.378***	-53.176***	8.782	-37.897*
	(1.051)	(0.680)	(16.283)	(14.457)	(12.035)	(19.756)
Period	0.341***	-0.056	1.085***	-0.662	0.157	1.217***
	(0.040)	(0.043)	(0.206)	(1.066)	(0.339)	(0.265)
Cap*Period	-0.238***	0.107**	1.773	-1.662	-3.461	1.539
	(0.080)	(0.051)	(2.268)	(3.110)	(2.978)	(2.126)
Tax*Period	-0.094	0.063	-0.241	-0.624	-0.508	0.167
	(0.102)	(0.047)	(0.349)	(1.363)	(0.552)	(0.680)
Constant	23.220***	14.920***	165.234***	157.963***	19.635***	182.857***
	(0.689)	(0.233)	(13.773)	(2.436)	(6.694)	(14.321)
N	728	642	752	752	752	752

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Robust standard errors clustered at the session level in parentheses. Marginal effects: standard errors estimated with delta method in parentheses.

Impacts of the regulations on quantity and per-period payoffs - Pooling only

	Dependent variable				
	q	$\mathbb{E}[\pi]$	U_H	U_L	Total Surplus
Cap	-4.920*	-31.527	-7.851	36.240	-36.557
	(2.562)	(27.810)	(20.783)	(26.304)	(29.002)
Tax	-8.506***	-71.579***	-83.510***	-13.467	-5.997
	(2.634)	(4.938)	(16.320)	(9.368)	(11.581)
Period	-0.109	1.308***	-1.562***	-0.662**	1.189***
	(0.079)	(0.396)	(0.333)	(0.296)	(0.310)
Cap*Period	0.249***	1.298***	0.643	-1.386***	1.562***
	(0.080)	(0.494)	(0.630)	(0.465)	(0.424)
Tax*Period	-0.023	-0.739	0.041	0.292	-1.822***
	(0.109)	(0.494)	(0.917)	(0.364)	(0.584)
Constant	18.375***	164.302***	177.446***	19.139**	182.693***
	(2.327)	(4.744)	(10.601)	(8.997)	(6.432)
N	302	302	302	302	302

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Robust standard errors clustered at the session level in parentheses. Marginal effects: standard errors estimated with delta method in parentheses.

Impacts of the regulations on quantity and per-period payoffs - Exclusive only

	Dependent variable				
	q	$\mathbb{E}[\pi]$	U_H	U_L	Total Surplus
Cap	-20.403***	-60.784***	-7.464	-	-74.336***
	(5.585)	(20.903)	(17.628)	-	(23.964)
Tax	-22.125***	-80.296***	-8.411	-	-56.184***
	(5.755)	(8.666)	(12.367)	-	(14.235)
Period	-0.533	2.474***	-3.196**	-	2.323***
	(0.407)	(0.733)	(1.468)	-	(0.798)
Cap*Period	0.565	-2.362***	4.924**	-	1.974**
	(0.407)	(0.741)	(1.902)	-	(0.870)
Tax*Period	0.797	-0.683	3.090*	-	1.662
	(0.498)	(0.866)	(1.696)	-	(1.328)
Constant	36.043***	141.557***	39.311***	-	158.698***
	(5.551)	(8.590)	(1.775)	-	(11.333)
N	151	180	180	-	180

$*$ Pr < 0.1, $**$ Pr < 0.05, $***$ Pr < 0.01. Robust standard errors clustered at the session level in parentheses. Marginal effects: standard errors estimated with delta method in parentheses.