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

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Abstract

We report a laboratory experiment designed to test the economic impacts of two regulations: specific taxes and portion cap rules (caps). Caps have been accused of reducing consumers' choice and well-being. In our experiment, single-product sellers face demand from two types of privately-informed buyers. We manipulate the policy environment across treatments. With regulations, we aim to reduce the size of the large option by an amount close to half the original quantity. With a tax, subjects are less likely to offer menus with two alternatives, suggesting that taxes reduce the choice set for buyers. We also 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 food policy where the assumption that caps reduce consumer choice and negatively impact buyers' surplus largely drives public debate; we find that these critics are misplaced.

Keywords: experiment, nonlinear pricing, quantity cap, specific tax

JEL classification: C9, D82

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1 Introduction

We report a laboratory experiment that contrasts the impacts of per-unit taxes and portion cap rules (caps) in a single-product market whit discrete privately-informed buyers.[1] Our experimental design is informed by nonlinear pricing theory. Holding the quantity-reduction goal for the largest option constant in the regulated treatments, we manipulate the policy environment with the intention of i) observing whether sellers modify their pricing strategies, ii) observe differences in quantities, and iii) measure how payoffs change across treatments, paying close attention to consumer's information rents. The results are informative to policy makers in charge of regulating consumption in markets where protection of consumer welfare is of primary concern, and where sellers adopt second-degree price discrimination as their main segmentation strategy.

Nonlinear prices are sorting mechanisms used by sellers to mitigate an asymmetric information problem.[2] According to the theory, the seller designs her pricing scheme relying on self-selection constraints to successfully separate different buyer types. 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 through his decision. The sellers' optimal price schedule is concave, implying decreasing marginal price per unit. 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 increasing rents (Maskin and Riley (1984); Myerson (1979); Mussa and Rosen (1978)). Examples of industries where nonlinear prices are common include cable television services with

[1]Portion cap rules are regulations that enforce an upper limit in the quantity at which a product can be offered.

[2]A complete study of the theory and its applications can be found in Wilson (1993)

"premium" services featuring 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" choice feature quantity discounts compared to the "small" option of the same product.

Our research can illuminate the consequences of adopting either caps or taxes in industries such as the examples mentioned above, but is perhaps more relevant to the case of food retailing, where both casual observation of the field and academic research suggest that price discrimination is rampant.[3] In this industry, both of the intervention tools under consideration have been either implemented or proposed with the explicit intention of discouraging consumption of large portions of products deemed unhealthy when consumed liberally. Specific taxes are often the first -and sometimes the only- option discussed when authorities in health-conscious localities plan their food policy, and their popularity is increasing. Take the so-called "soda taxes" as an example. In 2013, there were no cities in the United States with an approved tax exclusively targeting SSBs. As in October 2018, 7 localities, home of near 4 million residents, had taxes on SSBs in place. Mexico enacted a national "soda tax" in 2014. Less studied and discussed than taxes, caps are limits on the maximum default size at which sellers can offer a given food product. In light of a number of studies linking larger portion sizes to increased consumption, caps have arisen as a possible instrument to curb the consumption of unhealthy foods (Rolls et al. (2006), Ledikwe et al. (2005), and Flood et al. (2006)).[4]

[3]See, for example Bonnet and Réquillart (2013); Hendel and Nevo (2013), and Holton (1957)

[4] A prominent example is the so-called New York City's "soda ban". This regulation was originally proposed to take effect in New York City by 2013. The plan intended to prohibit the sale of SSBs in containers exceeding 16 ounces.As a reference, the "small", and "large" cup sizes typically found in popular American fast-food restaurants contain around 16, and 32 ounces correspondingly. The 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). Nonetheless, caps remain a viable option for food policy design elsewhere and remain an important alternative in jurisdictions where soda taxes have been either repealed or failed to be approved.

Opponents to caps argue that they are particularly harmful to consumers and reduce choice. The implication is that diminishing default sizes will result in smaller choice sets and lower consumer welfare. These concerns are rarely raised when discussing the application of specific taxes to discourage consumption of large portions. Our aim is to compare taxes and caps designed to reduce the large option of a product by the same amount and observe which regulation hurts consumers the most. This is relevant in the cited example of food retail regulation because the assumption that caps are uniquely harmful to consumers is already shaping public policy.[5] We posit that, because the concrete characteristics of the menu are defined by a price-discriminating seller, it is not straightforward to predict how exactly the sellers will endogenously modify their menus following an intervention. The different nature of alternative regulations may result in distinct pricing policies, which in turn would translate into different distributions of information rents. In short, it is difficult to readily predict how taxes and caps would alter consumer's surplus and choice set in markets characterized by adverse selection.

In a controlled laboratory experiment, we manipulate the policy environment across treatments to observe sellers' pricing behavior. Our goal is to generate a formal comparison between caps and specific taxes. If one policy is more likely to cause our sellers to offer less options compared to our baseline, we argue that the policy reduces consumer choice. Similarly, if consumer surplus is negatively impacted by a given intervention, we submit that the policy hurts buyers, and if one has a larger effect we conclude it hurts consumers more than the alternative.[6]

In our experiment, human participants trade with automated buyers, and the parameter values are such that separation of types is optimal regardless of the regulation context. We let human subjects taking the role of sellers trade with

[5] In the United States, for example, Mississippi's Bill 2687 (2013) interdicts against future restrictions of food sales within the state based upon the product's nutrition information or upon its bundling with other items.

[6] In this document, information rents and consumer surplus are used interchangeably, since any benefits or detriments attributable to health outcomes following the policies are abstracted away.

computer programs that mimic the choices of rational consumers to remove the confounding effects that strategic interaction between human buyers and sellers would bring about. This allows us to be confident in attributing changes in pricing and information rents to variations in the policy context. In addition, sellers should offer two packages to serve each type of buyer. Compared to a regulation-free baseline, our data suggests that subjects are as likely to offer two-item menus with cap rule, but less likely to offer two options under a tax regime. Moreover, we find that information rents are, in general, reduced when a per-unit tax is implemented, but not when a cap rule is enforced. These findings are important because the claims of a negative impact on both consumer choice and surplus are often made to disregard portion cap rules but virtually never raised when considering excise taxes.

We remain agnostic about the effectiveness of either taxes or caps to fight obesity. We do not advocate for the implementation of either regulatory alternative. Our objective is to use an economic experiment, informed by a stylized model, to find whether the ills of reduced choice sets and diminished information rents, often used to dismiss cap rules, can also be the result of taxes. The experimental evidence clarifies the manner in which price-discriminating vendors endogenously adapt their pricing schemes under different policy environments. To the degree that retailers of sugar-sweetened beverages and other foods adopt nonlinear pricing, and a main concern of authorities is the protection of consumer surplus, the present study can inform food policy design.

The rest of the document is organized as follows. The next section succinctly describes the related literature. In section three we introduce the model used to aid the experimental design and briefly discuss the theoretical outcomes of the interventions. In section four, we show our experimental design, and present the hypotheses we seek to test under laboratory conditions. We use the fifth section to provide a general overview of the data and analyze the demand segmentation resulting form subjects' behavior. In section six, we list the main results. The last part concludes.

2 Related literature

Our main contribution is the empirical comparison of the effects of per-unit taxes and caps in a market with discrete heterogeneous buyers. Our experimental design is informed by the work of Bourquard and Wu (2019) and Nuno-Ledesma et al. (2019). These documents leverage nonlinear pricing theory to analytically evaluate the consequences of implementing tax regimes and caps to regulate markets where sellers face adverse selection. They discuss that, because the buyer's preference remains private information, there is an incentive for the seller to engage in market segmentation, and alternative policy environments will distort these incentives differently. Theory predicts that reductions in welfare attributable to quantity caps are entirely explained by reductions in profit (Bourquard and Wu, 2019). This is not the case with per-unit taxes (Nuno-Ledesma et al., 2019). In this paper, we provide experimental evidence supporting these results.

Because specific taxes and caps have been discussed as alternatives to regulate consumption of sugar-sweetened beverages, we provide an overview of the literature exploring the application of these measures; especially important are studies looking at reduction in consumption, since the models used to aid experimental design predict diminished consumption. Regarding "soda taxes" there is a large and growing literature evaluating their efficacy at reducing consumption. A large proportion of academic studies find support for the hypothesis that such taxes do reduce consumption of the targeted beverages (see, for example Falbe et al. (2015); Grogger (2017); Silver et al. (2017), and Cochero et al. (2017)). These studies are largely observational and remain silent regarding the underlying mechanisms driving changes in pricing and allocation, our study offers empirical evidence in support of one such mechanisms, namely the endogenous response of price-discriminating sellers.[7]

[7]The literature looking at the impact of these taxes on population weight shows mixed results. Some studies suggest that there are no significant impacts, that these may not depend solely on the severity of the tax, or that may be offset by substitution (Aguilar et al. (2019); Fletcher et al. (2015); Fletcher et al. (2010b); Fletcher et al. (2010a)); while others suggest that the effects may be more susceptible among "high risk" populations (Sturm et al., 2010). Our study is not concerned

Regarding studies analyzing the effects of portion cap rules, Wilson et al. (2013) (henceforth WSF) conduct a behavioral simulation to assess the consumption impact of a portion limit on SSB. Subjects are asked how much they would hypothetically purchase. No actual consumption or exchange of money takes place. There are two conditions: baseline-menu with small and large options, and a restricted-menu without large options. Their key finding is that buyer purchase more soda in the restricted condition. This study provides valuable insights regarding the potential framing effect of a portion cap rule, however it lacks two important features that we do consider: salient economic incentives, and a non-passive menu designer.

Likewise, John et al. (2017) conduct a behavioral study that looks at consumers' reaction to a portion cap rule. Their design is incentive-compatible since subjects had to pay for their beverages. In their design, they compare consumers' reaction to two possible menu strategies that restaurants may implement after the policy. In their baseline, a small 16-oz cup and a 24-oz cup were offered; in their regulated treatment two options remained in the menu: one 16-oz and two 12-oz cups. They also look at the effects of free-refills. They find that subjects buy less drinks in the regulated treatment, and free refills increase consumption. Our study differs from that of John et al. (2017) in that our subjects take on the role of sellers, as opposed to buyers. We vary the policy condition across treatments and let sellers decide their pricing strategies. During our experiment, we refer to the abstract good with the generic name of "package" since the theoretical predictions from our model are independent of the type of product being offered. To implement our experiment, we adopt predictions from a standard nonlinear pricing model as presented by Bourquard and Wu (2019) and Nuno-Ledesma et al. (2019). Thus, our analysis is concerned with evaluating economic theory.

Even though there are experimental studies evaluating the theory of adverse

with demonstrating the effectiveness of the measures regarding weight and health outcomes, we briefly mention these studies for completeness. Importantly, though the consensus is that taxes *do not cause more* consumption of the target product.

selection (for example, Hoppe and Schmitz (2015)). To the best of our knowledge, we present the first empirical study comparing per-unit taxes and portion cap rules in a market with heterogeneous buyers. In our design, the regulations are set so that the size-reduction of large options is equivalent under both regulations.

Since our study assumes nonlinear pricing, we include a brief description of analytical papers looking at the effects that various regulations have on price discriminating sellers. Besanko et al. (1988) analytically studies the effect of imposing minimum quality standards, maximum price caps, and rate of return regulations on a monopolist facing demand from heterogeneous consumers. These authors find that rate of return rules negatively impact all buyer types, maximum-price caps affect high willingness to pay consumers, and minimum quality standards carry negative effects for higher types of consumers. Corts (1995) extended Besanko and co-authors' model to study a price-cap on the lowest quality level and finds that this regulation implies higher prices for some buyer types and that policy-induced quality changes are translated into socially inefficient surplus distribution.

3 Theory

In this section we describe the model from which we derive our hypotheses. We show the characterization of the seller's optimal separating pricing strategies in three policy environments: an unregulated *Baseline*, an environment with a portion *Cap* limiting the maximum quantity to about half the theoretically optimal size of the large package but above the size of the optimal quantity of the small option, and a third environment where a per-unit *Tax* is enforced.[8] We follow the theoretical framework used by Bourquard and Wu (2019), and Nuno-Ledesma et al. (2019).

Consider a standard adverse selection model in spirit of Mussa and Rosen (1978) and Maskin and Riley (1984). The single-product seller faces demand from buyers

[8]For completeness, we show the characterization of single-package schemes in the appendix A. We also discuss the issue of segmentation policy-switching in appendix B

with private preferences. There are two types of buyers defined by their preference for the product. With probability $(1-\beta)$, the buyer is a high-type (H) buyer who values the good highly. With probability β, the buyer is a low-type (L) and does not value the product as much. If an i-type buyer pays price p for a package containing q units of the good, he earns surplus $U_i = \theta_i u(q) - p$, where $u(\cdot)$ is a well-behaved utility function. Both seller and buyer have reservation values of zero. There is a cost of production c incurred by selling one unit of the product. The seller could implement one out of three possible pricing schemes:

1. Separating: The seller offers two contracts $[(p_H, q_H), (p_L, q_L)]$ targeting one type of buyer each.
2. Pooling: The seller offers a single "one-size-fits-all" package (p, q) that ensures participation of both types.
3. Exclusive: The seller offers a single package (p, q) that excludes participation of the Low-type buyer.

In the main text of the document, we discuss results from the separating strategy.

3.1 Regulation-free baseline

The seller chooses prices and quantities to maximize her expected profit subject to an incentive-compatibility (IC) constraint and the participation constraint for the L-type (PC):

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

The seller's objective function weights the profit contribution of serving a given buyer type by the probability of the customer she faces being of either type. As we will show, taxes and caps modify the optimization program in different ways: taxes distort profit contributions, while caps reduce the seller's choice space.

Importantly, the price-discriminating seller considers a set of two constraints to maximize her expected profit: a participation constraint (PC), and an incentive-compatibility constraint (IC). Because these restrictions play an important role on the outcomes of the regulations, we briefly discuss them. PC ensures that all buyer types are at least indifferent between not participating or purchasing one of the packages offered by the seller. To serve both consumer types, only the participation constraint of the lower type is relevant because its satisfaction automatically implies that the H-type finds the menu of options to be individually rational.

The IC restriction plays an essential role. We say a menu of two packages is incentive-compatible if the L-type buyer prefers package (p_L, q_L) over the alternative, and the H-type buyer prefers package (p_H, q_H) over the other option. In an incentive-compatible mechanism, the quantity increases with the value of the taste parameter θ_i, satisfying the monotonicity condition $q_H > q_L$. Because at the optimum the constraints bind with equality, we can substitute them into the expected profit function and re-express the seller's problem as in equation 2. Notice that the objective function is not linear with respect to quantity.

$$\max_{q_L, q_H} \quad \mathbb{E}\left[\pi\right] = \theta_L u(q_L) - c q_L + \left(\frac{1-\beta}{\beta}\right)\left[\theta_H u(q_H) - (\theta_H - \theta_L) u(q_L) - c q_H\right] \quad (2)$$

Depending on how prevalent L-types are in the population and how large the taste dispersion $(\theta_H - \theta_L)$ is, there are occasions where single-package strategies are preferable to separating schemes. Because our premise is that separation of types via nonlinear pricing is pervasive in the food industry, in our experimental design we choose parameters that ensure that demand segmentation is preferred. In the subsection below we characterize the optimal separating schemes for all three policy environments we consider in this paper.

3.1.1 Baseline

When the seller adopts a separating scheme, the quantities satisfy the first order conditions in 3.[9]

$$\text{Baseline-separating-quantities}\begin{cases}\theta_H u'(q_H^{*1}) = c \\ \theta_L u'(q_L^{*1}) = \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}\end{cases} \tag{3}$$

With these quantities (3), the L-type buyer is held at his reservation value receiving no surplus ($U_L = 0$). While the High-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 $T.S. = \mathbb{E}[\pi^{*1}] + U_H$. In short, the profit-maximizing schedule allocates larger quantities to the buyer with higher willingness to pay, grants positive surplus to the H-type, while it does not grant surplus to the L-type consumer.

The resulting separating schedule allocates to the H-type his first best quantity. This is the quantity at which this type's marginal willingness to pay equates marginal cost of production. The lower type buyer does not receive his first-best quantity because q_L does not equate marginal benefit for the L-type with marginal cost of production; in fact, this buyer receives less than his first-best quantity.

3.2 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 still chooses quantities to maximize expected profit expressed in 2, subject to the following portion cap rule (PCR):

[9] We use superscripts throughout the theory section as follows. The stars refer to the policy environment: one star (*) refers to the baseline, two to the market with a cap, and three stars refer to the tax policy. The numbers correspond to the segmentation strategy: number one (1) marks the separating scheme; number two labels the pooling scheme outcomes, and the number three refers to results from the taxed market.

$$\text{(PCR): } q_i \leq \hat{q} \quad \text{for} \quad i = L,\, H \tag{4}$$

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. $q_L^{*1} \leq \hat{q}$. Thus, our analysis is consistent with moderate restrictions that do not go as far as setting the limit below the quantity contained in the small alternative when there is no regulation enacted. The quantities satisfy:

$$\text{Cap-separating-quantities} \begin{cases} \theta_H u'(q_H^{**1}) \geq c, \text{ where } q_H^{**1} = \hat{q} \\ \theta_L u'(q_L^{**1}) = \frac{c}{\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right]} \end{cases} \tag{5}$$

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

If the regulation is set at a level strictly below the large unregulated quantity, then the H-type buyer consumes less of the product but does not see his consumer surplus diminished. The reason is that consumer surplus for the high type is pinned down by the quantity offered to the L-type which is not negatively impacted by a regulation where $q_L^{*1} \leq \hat{q} \leq q_H^{*1}$. 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 separating the demand.

3.3 Per-unit tax

The specific tax t_s modifies the seller's optimization program in the following way:

$$
\begin{aligned}
&\max_{(p_H,q_H,p_L,q_L)} \quad \mathbb{E}[\pi] = (1-\beta)\big[p_H - t_s q_H - c q_H\big] + \beta\big[p_L - t_s q_L - c q_L\big] \\
&\text{subject to} \\
&\theta_L u(q_L) - p_L = 0 \\
&\theta_H u(q_H) - p_H \geq \theta_H u(q_L) - p_L
\end{aligned} \tag{6}
$$

When the seller offers a menu of packages under taxation, the optimal quantities solve the following first order conditions:

$$
\text{Cap-separating-quantities} \begin{cases} \theta_H u'(q_H^{***1}) = t_s + c \\ \theta_L u'(q_L^{***1}) = \frac{t_s + c}{\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right]} \end{cases} \tag{7}
$$

With these prices and quantities, Low-type buyer receives no information rents. The High-type buyer receives $U_H^{***1} = (\theta_H - \theta_L)u(q_L^{***1})$. The seller's expected profit is $\mathbb{E}[\pi^{***1}] = \beta[\theta_L u(q_L^{***1}) - (t_s + c)q_L^{***1}] + (1-\beta)[\theta_H u(q_H^{***1}) - (\theta_H - \theta_L)u(q_L^{***1}) - (t_s + c)q_H^{*1}]$. Total surplus is $T.S. = \mathbb{E}[\pi^{***1}] + U_H^{***1} + t_s(q_H^{***1} + q_L^{***1})$. Thus, with a tax both types of buyers consume less of the product and receive a smaller surplus. This is because the tax is akin to an increase in cost of production. The fact that the tax distorts the quantity of the small package, is the cause for a reduction in the H-type's consumer surplus.

In principle, the tax can be set such that $q_H^{***1} = \hat{q}$ and we can compare the impacts on quantities, seller's earnings, and consumer surplus by type. We conduct an experiment to evaluate the impacts. In the next section we introduce our experimental design, and list the set of testable hypotheses.

4 Experimental design and hypotheses

We aim to evaluate the economic impacts of reducing the quantity of the large option from 31 units to 17.[10] Table 1 shows the parameters used in the experiment. We chose a parameter combination in which it is in the sellers' best interest to segment the demand by offering a menu of two incentive-compatible packages in all treatments. Thus, in theory, subjects should be as likely to offer two packages in both regulated treatments as they are in the control unregulated group. The model predicts that sellers will offer small and large packages. We chose the intervention levels (cap and tax) to be equivalent by the theoretical impact they would have on the size of the large unregulated package.

The experiment features three treatments. In our *Baseline* treatment there is no active regulation; in treatment *Cap* there is a limit on the maximum quantity sellers were allowed to offer per package, and in treatment *Tax* a per-unit fee was charged to sellers. Table 2 shows the treatment-specific payoff functions and the range of endogenous variables the subjects can choose from. In theory, sellers can engage in three segmentation strategies: they can serve both buyer types with two screening contracts (Menu); or serve both buyer types with a single one-size-fits-all option (Pooling), or serve only H-type buyers (Exclusive). Because the choice of quantities and prices was restricted to integer numbers, it is possible that more than one screening contract could result in the same expected profit. Thus, it is possible that more than one contract could maximize expected profit for a given segmentation strategy. Table 3 presents figures describing the contracts that result

[10] The reader might be curious about why it is that we decide to conduct a laboratory experiment with students taking the role of sellers to test our predictions, as opposed to hiring field professionals to participate as subjects in our study. There are several reasons for this decision, the main two are the following. First, It has been demonstrated that college students are better at following abstract instructions relative to field professionals (Cooper et al. (1999); Alatas et al. (2009)). Second, we are interested in testing predictions derived from economic theory and, as argued by Cason and Wu (2019), student are the most appropriate subject pool when addressing research questions closely tied to theory. This is because college students are a highly homogeneous group and statistical inference is easier when nuisance variation across treatments stemming from factors unimportant to the main question is minimized.

in the maximum expected profit for a given segmentation strategy.

The purported objective of caps is to set a limit on the largest options available to restrict consumption of the targeted product among consumers who typically buy the biggest alternative available. Translated to our experimental setting, a cap rule ought to limit the size of the largest option available when sellers price discriminate. Thus, the quantity limit in *Cap* is set to 17 units, which is close to half the size of the large option in the *Baseline* treatment (about 31 units). The per-unit fee 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 in the menu from about 31 to about 17 units.[11]

[11] 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. Current taxes on unhealthy foods 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 will also be null in more lenient cases.

Table 1: Parameter values used in the experiment

Variable or function	Value or form	Description
β	0.5	Probability of the buyer being high 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: Treatment-specific payoffs and endogenous variables' ranges

	Payoffs		Ranges	
Treatment	Seller	i-type buyer	p	q
Baseline	$p - 240 \cdot q$	$\theta_i \cdot q^{0.95} - p$	$[0, \ldots, 25000]$	$[0, \ldots, 90]$
Size-cap	$p - 240 \cdot q$	$\theta_i \cdot q^{0.95} - p$	$[0, \ldots, 25000]$	$[0, \ldots, 17]$
Tax	$p - 240 \cdot q - 7.35 \cdot q$	$\theta_i \cdot q^{0.95} - p$	$[0, \ldots, 25000]$	$[0, \ldots, 90]$

Table 3: Description of screening contracts that maximize seller's expected profit

		Menu			Pooling			Exclusive		
Variable	Treatment	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Large quantity	Baseline	30.88	30	32	15.5	15	16	31.78	30	34
	Cap	17	17	17	15.5	15	16	17	17	17
	Tax	17.2	16	18	9	9	9	17	17	17
Large price	Baseline	7727.25	7509	7999	3919	3799	4039	8018.11	7591	8551
	Cap	4353.33	4345	4362	3919	3799	4039	4426	4426	4426
	Tax	4410.8	4114	4609	2338	2338	2338	4426	4426	4426
Small quantity	Baseline	8.13	7	9						
	Cap	8	7	9						
	Tax	7	7	7						
Small Price	Baseline	2120.5	1840	2338						
	Cap	2089.67	1841	2338						
	Tax	1841	1841	1841						
U_H	Baseline	75.38	64.53	83.76	135.39	131.14	139.64	0.9	0.08	1.76
	Cap	73.04	64.37	81.37	135.39	131.14	139.64	0.37	0.37	0.37
	Tax	64.82	64.37	65.37	81.09	81.09	81.09	0.37	0.37	0.37
U_L	Baseline	0.96	0.45	1.90	0.24	0.13	0.35	0	0	0
	Size-cap	0.72	0.45	0.90	0.24	0.13	0.35	0	0	0
	Tax	0.79	0.79	0.79	0.45	0.45	0.45	0	0	0
$\mathbb{E}[\pi]$	Baseline	244	244	244	199	199	199	196	196	196
	Size-cap	222	222	222	199	199	199	173	173	173
	Tax	133	133	133	112	112	112	111	111	111

In *Baseline*, 32 two-package menus maximize seller's expected payoff; 2 offers result in the maximum expected payoff from pooling; 9 offers render the maximum expected payoff possible for exclusive contracts. In *Cap*, 3 menus maximize seller's expected profit; 2 offers render the maximum expected payoff for pooling strategies; 1 offer results in the maximum expected profit possible for exclusive schemes. In *Tax*, 5 two-options menus produce the maximum expected profit; 1 offer achieves the maximum expected seller's payoff for pooling strategies; 1 offer results in the maximum payoff for exclusive strategies.

4.1 Hypotheses

With the parameters we chose, the best pricing strategies for all three treatments consist of menus with two incentive-compatible packages. Thus, we expect most subjects to offer menus with two packages in all three treatments.

Hypothesis 1 - Separation of types: Because the best pricing schemes in the three treatments consist of two incentive-compatible options, we expect most subjects to attempt separation of buyer types by offering a menu with one small package and one large option in all experimental treatments.

Because separating the buyer types is optimal in all three treatments, the main hypotheses we test with the experimental data correspond to the economic impacts of the regulations when the seller offers two options to the buyer. For completeness however, we briefly discuss the impacts of the interventions when the seller adopts sub-optimal single-package schemes; but these will not be list as hypotheses. The patterns we identify in the data in the section below when testing our hypotheses will be reported as our main results, while the detection of other interesting data patterns will be reported as findings.

Testable hypothesis 2 presents the expected impacts on portions. The model predicts that the cap rule will result in smaller sizes offered to the H-type buyer and no impact on the serving portion offered to the L-type. On the other hand, according to the model, the small portion is reduced only by the tax.

Hypothesis 2 - Impacts on serving sizes: When the seller offers a two-package menu, the portion cap rule only reduces the size of the large package, while the specific tax results in smaller size for both small and large packages.

In hypotheses 3 to 5, we list the impacts on consumer surplus and expected profit predicted by the nonlinear pricing model.

Hypothesis 3 - Impacts on H-type buyer's consumer surplus: When sellers offer two-packages menus, the ordering of the H-type's consumer surplus is:

Baseline = *Cap* > *Tax*. That is, the H-type buyer's payoff is negatively impacted only when a reduction in quantity is achieved via a per-unit fee.

Hypothesis 4 - Impacts on L-type buyer's consumer surplus: When sellers offer two-packages menus, the ordering of the L-type buyers' information rents is: *Baseline* = *Cap* = *Tax*. That is, the L-type buyer's payoff is not impacted by any of the regulations.

Hypothesis 5 - Impacts on seller's expected earnings: When sellers offer two-packages menus, the ordering of the seller's expected profit is: *Baseline* > *Cap* > *Tax*. In other words, the sellers are better off without intervention, and their payoff is the lowest with a per-unit fee.

In sum, when the seller offers two-packages menus, reductions in welfare under the cap rule are entirely explained by reductions in expected profit. The tax negatively impact both sellers and buyers.

4.1.1 Outcomes with sub-optimal single-package offerings

For completeness, we briefly discuss what the impacts would be for sellers who adopt single-package strategies. The main objective of this subsection is to summarize theoretical outcomes shown in the appendix.

With no regulation, a pooling strategy offers the L-type's first-best quantity at a price that leaves the L-type with no surplus, while the H-type participates and enjoys positive information rents. If the seller adopts an exclusive scheme, then only the H-type participates acquiring his first-best quantity but receiving no rents.

The impacts on serving size, consumer surplus, and expected seller earnings when the retailer adopts a pooling strategy before and after the implementation of the regulation are:

- The pooling serving size, purchased by both types, is smaller only with a tax. It remains unchanged with a cap.

- H-type's earnings are negatively impacted by the tax, but remain unaffected with the cap rule.
- The L-type's surplus does not change under any policy scenario.
- Seller's earnings are diminished by both interventions.

The effects on quantity, consumer surplus, and expected seller earnings when the retailer adopts an exclusive strategy before and after the implementation of the regulation are:

- The exclusive portion size is smaller with both interventions cap rule and tax. This portion is acquired only by the H-type.
- H-type's earnings are not impacted by either intervention, since he is held at his reservation value at all times.
- The L-type's surplus do not change under any policy scenario because remains excluded from participation.
- Seller's earnings are diminished with both interventions.

With an exclusive scheme, the H-type buyer does not see his surplus reduced with neither the tax nor the cap rule because an exclusive scheme implies that the sellers incorporates the H-type's participation constraint as the only restriction in her optimization program. As a result, the H-type is held at his reservation value regardless of the policy environment.

4.2 Procedures

Three sessions per treatment were conducted from November 18th 2016 to January 23th 2017 at Purdue University's Vernon Smith Experimental Economics Laboratory. Each session had twelve participants drawn from a subject pool managed with ORSEE (Greiner, 2015) in which most volunteers are students at Purdue Universty.

In total, 108 subjects participated in the experimental sessions. The experimental interface was implemented using oTree (Chen et al., 2016). Subjects are not allowed to participate in more than one session. The structure of all sessions is the same: first, subjects answer pre-experimental quiz to make sure that they understand the instructions; then, there are six non-paying trading periods for subjects to become familiar with the computer interface; afterwards, there are twelve paying trading rounds; lastly, the subjects are ask to answer a post-experimental survey.[12]

In the laboratory, every human subject takes on the role of a seller and interacts exclusively with the computer assigned to them. A computer program performs the role of the buyer. Earnings for both seller and buyer are denominated in an experimental currency we call "points". At the end of the session, points are converted into cash at the rate of 100 points per US dollar. Seller and buyer earn points during trading periods. The trading period's sequence of events goes as follows: The seller first decides whether she wants to offer one, two or no packages; in a subsequent decision screen, she specifies price and quantity for each of the packages she wants to offer and submits the menu; then, the buyer is privately assigned a type and proceeds to purchase that package that maximizes his payoff; lastly, the seller observes a screen showing her the characteristics (quantities and prices) she submitted, the buyer's purchase action, her period earnings, and her accumulated earnings. For every trading period, the buyer taste parameter is randomly assigned to be θ_L or θ_H with equal probabilities and this assignment is never revealed to the seller. The buyer would reject any package resulting in negative surplus and rejects the entire menu altogether if all options result in negative surplus. Rejection of the entire menu results in zero earnings for both seller and buyer. If the buyer is presented with two options resulting in the same non-negative payoff, then the purchase decision is random with both options equally likely. If the seller decides not to offer a package, then seller and buyer earn zero surplus. Sellers started the session with

[12] For a copy of the instructions, feel free to contact the corresponding author.

a balance of 500 points in the *Tax* treatment, and had no starting balance in the other treatments. Average earnings in U.S. dollars were 28.03, 25.72, and 23.17 in the *Baseline*, *Cap*, and *Tax* treatments correspondingly.

The buyer's role is automated to minimize the chance of two possible distortions. Firstly, an automated buyer eliminates possible uncertainty the seller could have regarding the buyer's decision process. Because the seller knows that the buyer is programmed to purchase the package that maximizes his payoff contingent on his type, the seller can be sure that the computer program does not commit mistakes, that it is memoryless, and his decisions are not explained by any strategic behavior beyond utility maximization. In this manner, the laboratory conditions are such that the seller can feel free to explore with different screening strategies without worrying about the possible interpretations that a human buyer could give to her decisions. A second reason is that want to be sure that our results are not driven by inequity aversion. This is the regularity observed in several economic experiments wherein participants in laboratory economies give up some of their own payoff to avoid inequitable outcomes (Fehr and Schmidt, 1999). Deviations attributable to inequity aversion have been mostly studied in one-shot games such as the ultimatum game[13], and their role in experiments testing principal-agent theoretical outcomes is less understood. In an experimental test of the canonical adverse-selection problem, Hoppe and Schmitz (2015) find that inequity aversion explains subjects' decisions that deviate from strict profit-maximization although less often than in ultimatum games. Our subjects were presented with a more complicated action set compared to the document by Hoppe and Schmitz, adding worries regarding inequity aversion would only difficult the analysis without adding much insight to our analysis.

[13]For examples, see Hoffman et al. (1994) and Güth et al. (1982).

5 Results: Data overview

Outcomes encountered in the data for which we do not have a main hypothesis are presented as findings, while outcomes directly related to the hypotheses in section 4.1 are classified as results. Before we present our main results, we first explore the general patterns encountered in the data.[14] We are primarily interested in finding whether our subjects behave in ways consistent with the theory. Specifically, we look for evidence of: i) subjects attempting market segmentation more often than engaging in single-package pricing schemes, and ii) Participants in the active treatments reduce the quantity of the largest package by the same amount when attempting separation of buyer types, as the experimental design intends it.

5.1 Do sellers attempt to separate buyer types?

Sellers do offer two-option menus more often than single-package offers. Table 4 presents descriptive figures from within treatment outcomes. [15] This table shows the number of two-packages (menu) and single-package (single) offers submitted by the sellers; and average prices and quantities. For the moment, we do not divide single offers between pooling and exclusive. We find that the majority of offers submitted by sellers in the laboratory, are two-package menus. The proportion of menu offers are 67.9, 62.2, and 52.6 percentage points for the *Baseline*, *Cap* and *Tax* treatments correspondingly.

[14] The original database contains 1296 observations. We made the following modifications: 1) When the subject submitted two packages, but these had identical prices and quantities, we consider this offer to be a "single" package 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 leas 2600 points or more. In total, the observations of 5 subjects were removed; 2 from *Baseline*, 2 from *Cap*, and 1 from *Tax*. After trimming these outliers, we have a database 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.

Table 4: Submitted offers

	Baseline		Size Cap		Tax	
	Menu	Single	Menu	Single	Menu	Single
# 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***	

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 5: Buyers' purchases and average consumption

	Baseline		Size Cap		Tax	
	Menu	Single	Menu	Single	Menu	Single
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.

The majority of submitted offers contain two alternatives, but the proportion of menus is lower in the regulated groups compared to the baseline. One reason is a dampened incentive to separate given that the regulations reduce the difference in sellers' earning between the best separating schemes and the best single-package strategy. As shown in table 3, in *Baseline*, the seller would loose 18% of the maximum earnings possible if she were to adopt the best pooling scheme as opposed to a profit-maximizing separating strategy. In the *Cap* and *Tax* treatments, the corresponding reductions in expected profit if the seller submits the best pooling scheme instead of offering a profit-maximizing separating menu are 10% and 16%. The expected profit earned by the optimal separating scheme is 20% higher with no regulation, 22% higher cap, and 16% larger with a tax, compared to the best exclusive strategy. For the moment, we present this as a finding, later in the document in the section where we discuss the main results of the paper, we present formal evidence showing that sellers are indeed less likely to offer menus with a tax.

Finding 1 - Standard nonlinear pricing theory predicts that the seller designs a menu of two-packages regardless of the policy environment. Consistent with the theory, the majority of offers submitted by our subjects in all treatments are two-package menus. However, the proportion of two-options menus is smaller in the regulated treatments.

It would be natural to wonder about the achieved rate of success at separating types. We argue that, to the degree that our subjects' objective of offering two packages is to segment demand, they do so with relative success because large packages are often bought by H-type customers, while small packages are acquired by L-types. Table 5 exhibits descriptive figures from within treatments regarding the buyer's decisions. We notice that, in a majority of cases in all treatments, H-type buyers decide to purchase the large option when presented with a menu. Similarly, in the three treatments the majority of the time L-type buyers buy the small package when offered a menu. Moreover, comparing the prices and quantities reported in tables 4 and 5, we note that average price and quantities of small and large packages closely resemble the average prices and quantities of the packages actually purchased by low and high-type buyers, which suggests that mistakes committed by subjects, although possible and almost surely present in the data, are not driving the results. A high rate of errors or not-thoughtful submissions would cause a large discrepancy between offered price-quantity combinations and the price and quantities actually purchased by the buyers.

For completeness, we look at how often subjects satisfy relevant incentive constraints. In table 6 we show how often submitted offers satisfied relevant incentive constraints. The upper panel refers to menu offers. A menu is said to be incentive-feasible if it satisfies both the participation constraint of the low type and the incentive-compatibility constraint. Subjects submitted incentive-feasible menus more often in *Baseline* than in the regulated treatments.

Finding 2 - Standard nonlinear pricing theory predicts that the seller designs an incentive-feasible menu of two-packages to ameliorate an adverse selection problem, regardless of the policy environment. Consistent with the theory, the majority of menu offers submitted by our subjects in *Baseline* are incentive-feasible. Contrary to the theory, the majority of menu offers in both *Cap* and *Tax* are not incentive-feasible.

The lower panel in table 6 refers to single-package offers. Most offers satisfy the H-type PC in all treatments. The majority satisfy the L-type in *Baseline* and *Cap*, however the majority of offers do not satisfy the low-type PC. We interpret this last pattern as follows: Most single package offers were consistent with pooling strategies in both *Baseline* and *Cap*, in *Tax* however, subjects switched to favor exclusive pricing strategies. Underlying this interpretation is the following assumption:

Assumption 1 - We classify single-package offers as either a pooling or an exclusive offer according the following heuristic: if the offer satisfies the low-type participation constraint, we consider it to be a pooling offer; if the offer satisfies only the

Table 6: Satisfaction of incentive constraints

	Baseline	Cap	Tax
Menu offers:			
Incentive Feasible	172/277 (62.1)	98/254 (38.6)***	85/221 (38.5)***
Incentive Compatible	188/277 (67.9)	102/254 (40.1)***	105/221 (47.5)***
Participation Constraint (Low)	227/277 (81.9)	197/254 (77.6)	162/221 (73.3)**
Single offers:			
Participation Constraint (High)	130/131 (99.2)	138/154 (89.6)***	185/197 (93.9)**
Participation Constraint (Low)	90/131 (68.7)	115/154 (74.7)	97/197 (49.2)***

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.

participation restriction of the high-type buyer, then we consider it to be exclusive.

Because most single-option offers satisfy the participation restriction of at least the L-type buyer, reflected in the low rate of rejection of these class of proposals, suggests that subjects adopting single-package strategies understood the instructions and implemented their single-item strategies with relative success.

5.2 Do the interventions result in equivalent quantity reductions?

Recall that in theory, with the parameter combination we chose, both interventions ought to result in a reduction of the optimal quantity of largest package from 31 to 17 units. Ideally, in the regulated experimental groups, the reduction in size for the large options when sellers offer two-package menus should be identical. We find evidence that this is not the case. Sellers offer smaller packages with the specific tax. This is not surprising since the quantities subjects can offer in *Tax* are not strictly bounded. The main result in this paper is that only the tax reduces consumer surplus when sellers separate buyers. We argue that because the reduction of the large option's quantity is more pronounced in the cap treatment, our main results holds. In other words, even when the cap reduces the large serving size by a larger amount, it does not impact consumer surplus, while the tax does.

In the next section, we will discuss with detail the impacts of the regulations on the offered quantities. For now, to show that the regulations resulted in dissimilar impacts on the large serving size when the seller offered a menu, we look at the column titled "Large Quantity" in table 7. According to our estimates, both interventions cause a reduction in the large portion, however after performing a Wald test, we reject the hypothesis of equivalent reductions (p-value = 0).

Table 7: Estimated Impacts of the Regulations on Submitted Quantities - Menus

	Dependent variable	
	Large Quantity	Small Quantity
Cap	-13.206***	-4.070***
	(1.148)	(0.064)
Tax	-8.361***	-5.366***
	(1.152)	(0.404)
Period	0.256***	0.020
	(0.036)	(0.041)
Cap*Period	-0.134	0.129***
	(0.087)	(0.044)
Tax*Period	-0.130	0.225***
	(0.198)	(0.042)
Constant	27.297***	14.081***
	(0.725)	(0.056)
N	752	752

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend. "Large" packages are the offered packages with the largest quantity in the menu. If both packages happen to have the same quantities then the "large" package is the more expensive package. The dependent variable is the quantity submitted by the sellers.

The main result of this paper is that a negative impact on buyers is only found in the *Tax* treatment. The fact that subjects offer, on average, larger quantities in *Tax* and smaller options in *Cap* would work against this result. In other words, despite the fact that offers in *Cap* were smaller, the cap does not impact consumers, while the per-unit tax does. We present the evidence in the following sections.

6 Main results: Comparing the impacts of caps and taxes

In the previous section we showed data patterns that align with some of the main predictions of nonlinear pricing theory. In particular, most of the time our subjects attempted separating pricing schemes with relative success. This inspires confidence in the theory, experimental implementation, and subjects' comprehension of the instructions. We now turn to our main research goals, namely to test whether subjects attempt separation of types at the same rate under regulation as they do in the baseline; and estimate the regulations' impacts on consumer surplus. For completeness, we also look at the interventions' effects on total surplus, defined as the sum of expected profit and consumer surplus plus tax revenue where applicable. The first subsection addresses the effects when sellers offer two-package options, the second subsection looks at the outcomes when sellers adopt single-package schemes, while the last part succinctly presents the estimated changes in surplus when we pool the data regardless of the sellers' strategies. Because the main hypotheses presented in this paper concern the impacts of the regulations when sellers segment the demand, the main outcomes shown in the next subsection are listed as results; while the outcomes presented in the later subsections are listed as findings.

6.1 Impacts when sellers adopt two-package strategies

We begin by discussing changes in the probability of subjects submitting menus of two packages with the regulations. As we mentioned in the section above, the majority of offers in all treatments are menu offers. However, the share decreases in the regulated treatments. From the estimation of a logit model reported in table 8, the reduction in the probability of offering menus is only statistically significant in the *Tax* treatment.

Result 1 - Separation of types: *Although the majority of submissions contain*

Table 8: Probability estimates for two-packages offer

	Logit	
	Model	Marginal effect
Cap	-1.116	-0.078
	(0.760)	(0.063)
Tax	-2.071**	-0.170*
	(0.893)	(0.087)
Period	-0.086*	-0.005***
	(0.047)	(0.002)
Cap*Period	0.043	
	(0.055)	
Tax*Period	0.045	
	(0.065)	
Constant	2.748***	
	(0.798)	
N	1236	1236

$*$ Pr < 0.1, $**$ Pr < 0.05, $***$ Pr < 0.01. Models: Robust standard errors clustered at the session level are in parentheses. Marginal effects: standard errors estimated with delta method are in parentheses. Cap dummy takes a value of 1 if the observation belongs to the size-cap treatment. Tax dummy takes a value of 1 if the observation belongs to the tax. Period is a time trend. The dependent variable takes a value of 1 if the seller offered a two-packages offer, 0 otherwise.

two packages in all treatments, in alignment with hypothesis 1, the subjects were significantly less likely to offer menus in the Tax *treatment.*

One of the arguments usually raised against portion cap rules is that they reduce consumer choice. However, our data suggests that buyers are offered two options in the *Cap* at, on average, the same rate that they are offered two-package menus in the *Baseline*. On the other hand, sellers are less likely to offer menus with two alternatives in the *Tax* treatment.

We proceed now to the discussion of the interventions' impacts on offered quantities. We showed table 7 when discussing whether the reduction in large serving sizes was equivalent across the active treatments. Table 7 shows estimated impacts on the large and small packages when sellers offered two-option menus. The coefficients on both treatment dummy variables are negative and significant. We include a time trend (period) and interact it with the treatment dummy variables to control for possibly different rates of learning. In the case of quantities, if the coefficient on the time trend is positive and significant, it would imply that subjects "learn" to offer larger quantities as the game progresses. A significant coefficient on the interaction between a given active treatment and the trend would imply that, to the degree that learning was present in the baseline, the rate at which subjects learned differed in the regulated treatment.

As we already mentioned in the previous section, both regulations reduce the portion of the large serving size, but the impact is larger with a cap. Regarding the quantities contained in the small packages, the estimated coefficients seem, at first sight, equivalent; however, results from a Wald test reject the null hypothesis of the impacts being equal (p-value 0.001). That the average size of the small package suffers a larger reduction under a tax is aligned with the model's predictions. We list these results below.

Result 2 - Impacts on serving sizes: *Both* Tax *and* Cap *reduce the quantities of both portion alternatives (large and small). The average quantity of the large* *alternative is smaller in the* Cap *treatment. The size of the small serving size is smaller in the* Tax*.*

The outcomes listed in result 2, mostly align with the theoretical hypotheses. The model predicts reductions in the size of the large option in both treatments and a reduction in size of the small package in the *Tax* treatment. Although we observe that the quantity offered in the small package is affected by both polices, the reduction in *Tax* is more pronounced.

Table 9 shows econometric estimates of the impacts of the regulations on per-period earnings when sellers offered two-options menus. The first column shows effects on expected profit; the second and third columns include estimated impacts on consumer surplus for the H and L-types respectively, and the last column exhibits the estimated effects on consumer surplus including tax revenue (included only for the *Tax* treatment). Surprisingly, even though in the *Cap* treatment the portion quantities are smaller for both types, we do not observe a reduction in consumer surplus. On the other hand, consumer surplus for H-types is negatively impacted in the *Tax* treatment. We list these outcomes in results 3 to 5.

Result 3 - Impacts on H-type buyer's consumer surplus: *According to hypothesis 3, when sellers offer two-package menus, the H-type's consumer surplus is negatively impacted in treatment* Tax*.*

Result 4 - Impacts on L-type buyer's consumer surplus: *According to hypothesis 4, when sellers offer two-package menus, we find no statistically significant impacts on L-type's consumer surplus in neither treatment.*

Result 5 - Impacts on seller's expected earnings: *According to hypothesis 5, when sellers offer two-package menus, seller's expected profit is smaller in the* Tax *group compared to the Baseline. However, in opposition to the hypothesis, when sellers offer two-package menus, there is no statistically significant decline in expected per-period profit.*

Results 3 and4 regarding changes in consumer surplus align with the theoretical

Table 9: Estimates of the Impacts of the Regulations on Per-period Payoffs - Menus

	Dependent variable			
	$\mathbb{E}[\pi]$	U_H	U_L	Total Surplus
Cap	-38.521	3.238	30.548	-44.294*
	(26.110)	(32.294)	(26.293)	(25.660)
Tax	-97.378***	-53.176***	8.782	-37.897*
	(16.283)	(14.457)	(12.035)	(19.756)
Period	1.085***	-0.662	0.157	1.217***
	(0.206)	(1.066)	(0.339)	(0.265)
Cap*Period	1.773	-1.662	-3.461	1.539
	(2.268)	(3.110)	(2.978)	(2.126)
Tax*Period	-0.241	-0.624	-0.508	0.167
	(0.349)	(1.363)	(0.552)	(0.680)
Constant	165.234***	157.963***	19.635***	182.857***
	(13.773)	(2.436)	(6.694)	(14.321)
N	752	752	752	752

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Total surplus includes tax revenue. Explanatory dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend.

predictions. A natural way of explaining these effects in surplus given the changes in quantities reported in 7 is to look at changes in per-package prices. In table 10, we report econometric estimates of the impacts on prices as submitted by the sellers. Consumers remain unaffected by the portion cap rule because sellers adjust prices down to keep consumer surplus unchanged across the regulated environments. The intuition is simple: because the incentive to separate buyer types exists in all policy environments, the seller has an incentive to keep offering information rents to the H-type consumer.

In result 5, we mention that the observed effect on the seller's expected earnings in the *Tax* treatment aligns with our hypothesis. However we observe no change in expected earnings in *Cap* treatment. An explanation of why expected profit does not change in this case, is that sellers adjusted their prices in such a way that the profit contributions made by selling large and small packages remained equal

Table 10: Estimated Impacts of the Regulations on Offered Prices - Menus

	Dependent variable	
	Large Price	Small Price
Cap	- 2451.75***	-441.699
	(462.331)	(482.965)
Tax	-1749.032***	-999.892**
	(268.854)	(486.051)
Period	56.727***	2.274
	(8.858)	(11.408)
Cap*Period	-33.039*	20.687
	(18.894)	(15.211)
Tax*Period	-35.245	87.977**
	(39.887)	(36.968)
Constant	6801.307***	3597.123***
	(213.388)	(8.760)
N	752	752

$*$ Pr < 0.1, $**$ Pr < 0.05, $***$ Pr < 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend. "Large" packages are the offered packages with the largest quantity in the menu. If both packages happen to have the same quantities then the "large" package is the more expensive package. The dependent variable is either quantity or price (as noted) submitted by the sellers.

across the unregulated and quantity-limited treatments. The profit contribution of a sold package is the difference between its price and its cost of production. In table 11, we present econometric estimates of the impact of regulations on the profit contributions of large and small options and their sum. Profit contributions of both types of packages decreased in *Tax*. In *Cap*, the fall in profit contributions made by the large packages is barely significant; while the contributions of small options are statistically equivalent to the baseline. This suggests that under a portion cap, sellers adjust both quantity and prices so that the sum of profit contributions remains unchanged compared to the *Baseline* treatment.

Table 11: Estimated Impacts of the Regulations on Profit Contributions - Menus

	Dependent variable: Profit contribution		
	Large Package	Small Package	Sum of Profit Contributions
Cap	-48.252*	-33.096	-78.960
	(28.259)	(28.359)	(56.654)
Tax	-108.643***	-93.318***	-202.278***
	(14.140)	(17.299)	(35.894)
Period	2.315***	0.068	2.220***
	(0.769)	(0.315)	(0.127)
Cap*Period	1.396	3.396	4.987
	(2.296)	(2.840)	(5.228)
Tax*Period	0.062	0.241	-0.814
	(1.012)	(0.600)	(1.206)
Constant	188.588***	162.509***	347.589***
	(12.835)	(14.541)	(28.258)
N	728	642	642

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Total surplus includes tax revenue. Explanatory dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend.

Here we end the discussion of our main results, namely the expected outcomes attributable to the regulations as predicted by nonlinear pricing theory when sellers offer menus of two packages to segment buyer types. In the subsection below, we discuss the changes in the variables of interests when the sellers offer contracts with a single package.

6.2 Impacts when sellers adopt single-package strategies

Table 12 presents our estimates on offered quantities. The first column shows the estimated impacts for pooling offers, while the second column presents results for exclusive offers.

Finding 3 - *In both regulated treatments, sellers implementing a single-package (either exclusive or pooling) strategy offered smaller quantities.*

Looking at pooling strategies, the reductions registered in the *Cap* and *Tax*

Table 12: Estimated Impacts of the Regulations on Quantities - One Package Offers

	Pooling	Exclusive
Cap	-4.920*	-21.082***
	(2.562)	(7.076)
Tax	-8.506***	-17.728**
	(2.634)	(7.267)
Period	-0.109	-0.336
	(0.079)	(0.481)
Cap*Period	0.249***	0.412
	(0.080)	(0.484)
Tax*Period	-0.023	0.672
	(0.109)	(0.695)
Constant	18.375***	33.281***
	(2.327)	(7.047)
N	302	180

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend. "Pooling" observations satisfy the participation constraint of the L-type. "Exclusive" schemes satisfy the participation constraint of the H-type only. The dependent variable is the quantity submitted by the sellers.

treatments are not equivalent (Wald test p-value = 0.03). Likewise, a Wald test under testing the null hypothesis of an equivalent reduction across regulated treatments when sellers adopt exclusive schemes returns a p-value of 0.08. Thus we can reject the hypothesis of equivalent impact on exclusive quantities at the 10% level. According to the model and from results listed in the appendix, assuming that sellers do not change their strategy following the intervention, the serving size would always decrease, except when the seller is implementing a pooling scheme and the regulation is a portion cap rule.

In table 13, we present our estimates of the impact of the regulations on seller's earnings, expected profit, information rents, and aggregated surplus. We find no evidence of significant reductions in neither expected profit, consumers' surplus, nor total surplus in *Cap*. While on the other hand, expected profit and H-type buyers' rents are lower in the *Tax* treatment. Tax revenue is high enough so as to keep total surplus unaffected in *Tax*. According to the theoretical predictions shown in the appendix and briefly discussed in the main text, the only regulation affecting consumer surplus when sellers pool the demand is the specific tax.

Table 13: Estimated Impacts of the Regulations on Per-period Payoffs - Pooling

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

$*$ Pr < 0.1, $**$ Pr < 0.05, $***$ Pr < 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Total surplus includes tax revenue. Explanatory dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend. Offers are classified as "pooling" if the seller offers one package and it satisfies the participation constraint for the Low type.

Finding 4 - *When the seller adopts a pooling strategy, the H-type buyer's surplus is found to be negatively impacted only in the* Tax *treatment. The L-type's surplus is not reduce by the regulations.*

In table 14 we show the interventions' impact on the payoff variables of interest considering exclusive submissions. As anticipated, expected profit is lower in both active treatments, however we cannot reject the hypothesis of the estimated impact

Table 14: Estimated Impacts of the Regulations on Per-period Payoffs - Exclusive

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

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Total surplus includes tax revenue. Explanatory dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend. Offers are classified as "pooling" if the seller offers one package and it satisfies the participation constraint for the Low type.

in *Cap* and *Tax* to be equal. Similarly, total surplus is reduced in both regulated treatments, and the reductions are not statistically different. Buyers' consumer surplus is not impacted by the regulations. These outcomes align with the theoretical model's outcome presented in the appendix.

Finding 5 - *When the seller adopts an exclusive strategy, the H-type buyer's surplus is not impacted by either regulation. The L-type's surplus is not reduce by the interventions.*

Thus, we see that when looking at observations where the seller implements a single-package scheme (either pooling or exclusive), we find reductions in consumer surplus only in the *Tax* treatment, as we observed when analyzing two-item offers.

6.3 Surplus impacts with the aggregated data

A natural question is whether we would observe different impacts when looking at the aggregated data (without parsing the data depending on the subjects' strategy). In table 15, we show econometric estimates of the impact of both intervention on seller's expected profit, consumer information rents, and total surplus. These estimates are aggregated, meaning that for the moment we put aside the fact that sellers in the laboratory engage in a mix of segmentation strategies (menu, pooling and exclusive). Compared to the unregulated benchmark, seller's payoff and expected profit are estimated to be lower in both active treatments and these impacts are not statistically equivalent (Wald p-value 0.009). High-type buyers are worse-off in *Tax*, but their informational rents are not lower in *Cap*. Low-type buyers' remained unchanged. We list these outcomes in the following finding.

Finding 6 - On aggregate:

- Sellers are affected by both regulations. They are worse-off in *Tax* than in *Cap*.
- High-type buyers' information rents are negatively impacted only under taxation.
- Low-type buyers' are not impacted by any intervention.

Thus, when we aggregate the data and ignore the segmentation scheme adopted by the seller, we find that L-type buyers are not impacted by the regulations, while H-type's are negatively affected only in the *Tax* treatment.

7 Conclusion

In this document, we report a laboratory experiment on single-product nonlinear pricing whith contracting restrictions. We compare two interventions that have been proposed as alternatives to restrict the consumption of foods judged to have

Table 15: Estimated Impacts of the Regulations on Per-period Payoffs - Aggregated

	Dependent variable			
	$\mathbb{E}[\pi]$	U_H	U_L	Total Surplus
Cap	-33.305*	-2.662	20.536	-39.089*
	(19.567)	(17.457)	(14.688)	(20.156)
Tax	-93.562***	-67.864***	-2.751	-44.378**
	(13.244)	(10.994)	(7.266)	(17.781)
Period	1.612***	-1.397	-0.201	1.727***
	(0.212)	(0.931)	(0.274)	(0.261)
Cap*Period	1.901	-0.420	-2.560	1.894
	(2.048)	(2.020)	(1.790)	(2.055)
Tax*Period	-0.506*	0.625	-0.175	0.104
	(0.294)	(1.414)	(0.404)	(0.652)
Constant	164.545***	149.834***	19.634***	182.267***
	(11.550)	(2.917)	(4.363)	(12.499)
N	1236	1236	1236	1236

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Total surplus includes tax revenue. Explanatory dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend.

deleterious effects on human health, particularly sugar-sweetened beverages (SSB). Our goal is not to advocate for or against cap rules or taxes. We are agnostic about whether regulating the consumption of SSB will have a significant impact on the population's health and weight. We outline the economic effects of both regulations in a controlled environment and contrast them.

Our findings largely corroborate the theoretical predictions. Our main finding is that, in general, the portion cap rule does not reduce buyers' consumer surplus while in the *Tax* treatment, buyers with high willingness to pay for the product are negatively impacted. This suggests that, surprisingly, portion cap rules do not negatively impact consumer surplus while taxes do. We also find evidence suggesting that taxes reduce the likelihood with which sellers offer two-package menus, as opposed to single-option menus. Subjects are as likely to offer two-package menus with a cap rule as they are in the baseline. In the context of food policy design, this finding is notable and highlights an effect produced by per-unit taxes that is not often discussed in public debates. It implies that, for a given quantity-reduction goal, taxes are more likely to reduce the consumers' choice set and caps do not seem to have a negative impact in the number of options offered by the seller.

We look to the degree at which the above results hold when looking at groups of sellers that engage in specific segmentation strategies. We find that when sellers offer menus, consumers of both types are not impacted by the cap, but sellers do. With a tax, high-type buyers are negatively impacted. Our subjects submit offers that leave expected profit unchanged with a cap, but lower with the tax. In short, when sellers engage in separating schemes, the cap rule does not impact consumers' information rents, but the tax does. An identical conclusion is drawn after looking at the data for sellers that adopt pooling strategies. We also determine that consumers are not affected by either regulation when sellers target high-type buyers exclusively since these buyers are held at their reservation values.

We would like to mention potential limitations of our study. First, this is a laboratory experiment and thus its limited external validity is limited. The laboratory context is appropriate for our purpose of testing predictions form a highly stylized theoretical model. This is the first step from pure theory to the field. Future studies that gradually incorporate specific attributes of given industries (e.g. the soda retail industry or any other where sellers price-discriminate and can potentially be regulated by taxes or caps) will aid to the understanding of soda seller's behavior under different policy contexts.

Second, subjects serve only two types of buyers, rather than buyers with taste parameters drawn from a continuous distribution of possible types. We chose this design for two main reasons: so that the design of discrete alternatives were the natural strategy for the seller, and to preserve parsimony. Under optimal pricing, as noted by Bourquard and Wu (2019), the seller offers as many options as there are buyer types. Therefore, a mass of buyers distributed along a continuum would result in the seller offering a continuous number of options, in a way that does not resemble the practices of food vendors whose menus feature a discrete and finite number of options. If more than two types were added to the design, the insights we could gain would come at the expense of complexity in instructions that would difficult the ease of understanding of the task at hand for participants. In general we favor parsimony and abstracting away from institutional details. We believe this decision to examine a basic problem will prove beneficial. We are convinced that comprehending how price-discriminating subjects react to different interventions in a fairly simple environment with discrete types sheds light to our understanding of the basic mechanisms behind the potential outcomes of quantity limits and taxes in the food retail industry and elsewhere.

Third, consumer surplus impact stemming from health benefits resulting from the regulations is absent. This is to retain the degree to which the results can generalize to industries where regulating would not produce health benefits. Undoubtedly, researchers taking the results discussed here interested to bring a health dimension to the problem should model health benefits.

Lastly, 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. As a first empirical study comparing taxes and caps in a setting with heterogeneous buyers, this is beneficial, rather than detrimental, to our work. We provide an early study based on classical and 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.

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Appendix A: Characterization of single-package strategies

Baseline - Pooling

When the seller decides to offers a one-size-fits-all option, she effectively ignores the IC restriction. The only participation constraint to consider is that of the L-type. The resulting mechanism is defined by a single quantity which satisfies the following.

$$\text{Baseline-pooling-quantity} \begin{cases} \theta_L u'(q^{*2}) = c \end{cases} \tag{8}$$

The Low-type buyer does not receive rents ($U_L = 0$). The H-type earns $U_H^{*2} = (\theta_H - \theta_L)u(q^{*2})$. Expected profit is $\mathbb{E}[\pi^{*2}] = \left[\theta_L u(q^{*2}) - cq_L^{*2}\right]$. Total surplus is $\mathbb{E}[\pi^{*2}] + U_H^{*2}$. In sum, a single package is offered resulting in zero surplus for L-type, positive surplus for the H-type. In this case, the produced quantity equals the first-best quantity for the L-type.

A pooling scheme is not always in the seller's best interest. In general she will decide too pool the demand when the taste dispersion $(\theta_H - \theta_L)$ is sufficiently small, or when the mix of Low to High types is such that it is prohibitively expensive to grant information rents to the H-type buyers. The exact points at which these conditions hold true depend on the parametrization of the model.

Baseline - Exclusive

When the seller prefers to exclude Low-types, she will only consider the participation constraint of the H-type buyer ($\theta_H u(q_H) = 0$). She sets a single quantity such that the following condition is satisfied:

$$\text{Baseline-exclusive-quantity} \begin{cases} \theta_H u'(q^{*3}) = c \end{cases} \tag{9}$$

With this scheme, neither type of buyer receives positive consumer surplus. Total surplus equals expected profit which is $\mathbb{E}[\pi^{*3}] = \left[\theta_H u(q^{*3}) - cq_L^{*3}\right]$.

Exclusive schemes are not always in the sellers' best interest. In general, it is only optimal to exclude the Low types if either taste dispersion $(\theta_H - \theta_L)$ is sufficiently large, the proportion of L-types β is sufficiently low.

Cap - Pooling

$$\text{Cap-pooling-quantity} \begin{cases} p^{**2} = \theta_L u(q^{**2}) \\ \theta_L u'(q^{**2}) = c \end{cases} \tag{10}$$

When the seller pools the demand, the Low-type buyer does no rents. The H-type earns $U_H^{**2} = (\theta_H - \theta_L)u(q_L^{**2})$. Expected profit is $\mathbb{E}[\pi^{**2}] = \left[\theta_L u(q^{**2}) - cq_L^{**2}\right]$. Total surplus is $\mathbb{E}[\pi^{**2}] + U_H^{**2}$.

Cap - Exclusive

$$\text{Cap-pooling-quantity} \begin{cases} \theta_H u'(\hat{q}) = c \end{cases} \tag{11}$$

In this case, the Low-type buyer is excluded. High-type does not receive information rents. Total surplus equals expected profit which is $\mathbb{E}[\pi^{**3}] = \left[\theta_H u(\hat{q}) - c\hat{q}\right]$.

Tax - Pooling

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

With this pooling strategy, neither buyer earns information rents. The seller's expected profit is $\mathbb{E}[\pi^{***2}] = [\theta_L u(q^{***2}) - t_s q^{***2}]$.

Tax - Exclusive

$$\text{Tax-exclusive-quantity} \begin{cases} \theta_H u'(q^{***3}) = t_s c \end{cases} \tag{13}$$

With an exclusive strategy, only the seller earns a positive payoff. Her expected profit is $\mathbb{E}[\pi^{***2}] = [\theta_L u(q^{***2}) - t_s q^{***2}]$.

Appendix B: Baseline single-option schemes

In the unregulated case, when can we expect to see a seller adopting a single-item strategy (either pooling or exclusive)? To answer this question, we compare the level of expected profit that the seller would attain by adopting one of the single-package schemes to the level of expected profit she would gain by separating the demand.

Let us begin with the case of serving high-types exclusively. The seller will serve the H-type only if the following inequality holds true:

$$\left(\frac{1-\beta}{\beta}\right)(\theta_H-\theta_L)u(q_L^{*1}) \geq \theta_L u(q_L^{*1}) - cq_L^{*1}$$

Intuitively, the seller will adopt an exclusive strategy if providing the H-type with information rents is costly enough. Specifically, when the information rents needed to be provided to H-type are larger than the profit contribution earned by serving L-types.

The seller will adopt a one-size-fits-all type of strategy if the following inequality holds:

$$\theta_L u(\tilde{q}) - c\tilde{q} \geq \beta[\theta_L u(q_L^{*1}) - cq_L^{*1}] + (1-\beta)[\theta_H u(q_H^{*1})(\theta_H-\theta_L)u(q_L^{*1}) - cq_H^{*1}]$$

Where $\tilde{q}$ is the optimal quantity served when the seller offers a single package to serve both types.

Regarding regulated environments, Bourquard and Wu (2019) and Nuno-Ledesma et al. (2019) show the necessary conditions needed for the seller to switch from a separating strategy to a single-package scheme for size caps and taxes, respectively. We discuss the results from these papers here.

In short, with a size cap of the severity we study in this paper, the profit-maximizing seller does not switch away from a segmentation strategy.

Regarding strategies with a tax, the separation scheme is preferred over the exclusive option if $\beta \geq \frac{(\theta_H-\theta_L)u(q_L^{***1})}{\theta_H u(q_L^{***1}) - cq_L^{***1}}$. This implies that there is a threshold that the proportion of low types must be above of for separation to be preferred. Because of the effects of the tax on quantities, the range of values of β for which separation of types is preferred diminishes, thus it is more likely for sellers to exclude L-types. At the same time, it is less likely that sellers will implement a pooling scheme.

Appendix C: Impacts on consumed quantities and paid prices

Table 16: Estimates of the Impacts of the Regulations on Purchased Quantities.

	Menu		Single-package	
	Large Quantity	Small Quantity	Pooling	Exclusive
Cap	-9.366***	-2.657***	-4.920*	-20.403***
	(1.259)	(0.678)	(2.562)	(5.585)
Tax	-11.119***	-5.790***	-8.506***	-22.125***
	(1.051)	(0.680)	(2.634)	(5.755)
Period	0.341***	-0.056	-0.109	-0.533
	(0.040)	(0.043)	(0.079)	(0.407)
Cap*Period	-0.238***	0.107**	0.249***	0.565
	(0.080)	(0.051)	(0.080)	(0.407)
Tax*Period	-0.094	0.063	-0.023	0.797
	(0.102)	(0.047)	(0.109)	(0.498)
Constant	23.220***	14.920***	18.375***	36.043***
	(0.689)	(0.233)	(2.327)	(5.551)
N	728	642	302	151

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend. Offers are classified as "menu" if the seller offers two packages. Offers are classified as "pooling" if the seller offers one package and it satisfies the participation constraint for the Low type. Offers are classified as "exclusive" if the seller offers one package and it does not satisfy the participation constraint of the low type. The dependent variable is quantity purchased by the i-type buyer (as noted).

Table 17: Estimates of the Impacts of the Regulations on Paid Prices.

	Menu		Pooling	Exclusive
	H-type	L-type	Price	Price
Cap	-2292.165***	-665.107***	-1211.716*	-4944.073***
	(291.036)	(137.233)	(627.265)	(1325.582)
Tax	-2683.968***	-1408.904***	-2039.885***	-5382.364***
	(263.252)	(170.335)	(639.238)	(1364.978)
Period	84.182***	-13.000	-25.201	-124.526
	(10.411)	(10.302)	(18.874)	(96.960)
Cap*Period	-56.561***	26.717**	61.403***	130.319
	(19.124)	(11.678)	(19.138)	(97.001)
Tax*Period	-20.497	15.272	-7.351	191.336
	(24.942)	(11.179)	(26.435)	(119.488)
Constant	5755.272***	3732.082***	4575.425	8976.21***
	(175.544)	(45.728)	(561.589)	(1314.311)
N	728	642	302	151

$*$ Pr $<$ 0.1, $**$ Pr $<$ 0.05, $***$ Pr $<$ 0.01. Models estimated using multi-level random effects (at the session and subject levels). Robust standard errors clustered at the session level. Dummy variables (Cap and Tax) denote whether the observation belongs to the corresponding treatment. Period is a time trend. Offers are classified as "menu" if the seller offers two packages. Offers are classified as "pooling" if the seller offers one package and it satisfies the participation constraint for the Low type. Offers are classified as "exclusive" if the seller offers one package and it does not satisfy the participation constraint of the low type. The dependent variable is price paid by the i-type buyer (as noted).