ESSAYS IN NONLINEAR PRICING UNDER REGULATION: ANALYSIS OF INTERVENTIONS ON FOOD RETAILING

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Jose Guadalupe Nuno-Ledesma

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

December 2018

Purdue University

West Lafayette, Indiana

THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF DISSERTATION APPROVAL

Dr. Joseph V. Balagtas, Chair
Department of Agricultural Economics

Dr. Steven Y. Wu, Chair
Department of Agricultural Economics

Dr. Bhagyashree Katare
Department of Agricultural Economics

Dr. Timothy N. Cason
Department of Economics

Approved by:

Dr. Nicole J. Olynk Widmar
Head of the Graduate Program

> The prudent man always studies seriously and earnestly to understand whatever he professes to understand, and not merely to persuade other people that he understands it; and though his talents may not always be very brilliant, they are always perfectly genuine.
>
> —Adam Smith, *The Theory of Moral Sentiments* (1759)

I owe everything to my family. Flawed as I am, I would not be here without them.

ACKNOWLEDGMENTS

This dissertation is possible thanks to the help I received from my advisory committee. I would like to express my sincere gratitude to my co-advisors Professors Joseph Balagtas and Steven Wu because they have been very patient and have offered inestimable support for which I feel indebted. I thank Professor Bhagyashree Katare who offered me continuous guidance and always had time to listen to my questions. I also feel grateful to Professor Timothy Cason not only because he kindly granted me access to the Vernon Smith Experimental Economics Laboratory which he directs, but because he also offered valuable and insightful comments that helped my research.

I would also like to thank Dr. Nelson Villoria, with whom I worked during the first year of my doctoral studies. I appreciate the help I received from the clerical staff of the department. I gratefully acknowledge that the research presented in this dissertation was possible thanks to the financial support from the United States Department of Agriculture's National Institute of Food and Agriculture.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

Table Page

LIST OF FIGURES

ABSTRACT

Nuno-Ledesma, Jose G. Ph.D., Purdue University, December 2018. Essays in Nonlinear Pricing Under Regulation: Analysis of Interventions on Food Retailing. Major Professors: Dr. Joseph V. Balagtas and Dr. Steven Y. Wu.

In this dissertation I present three essays. The overarching theme of these projects is how price-discriminating sellers endogenously modify their pricing schemes in the face of regulatory interventions. The application I have in mind when writing the papers is that of a food retailer deciding menu characteristics, such as price and quantity, in the context of a given food policy environment. The particular policies I consider are portion cap rules and taxes, both designed by the policy-maker to reduce the consumption of certain foods and ingredients. My approach diverges from studies focusing on buyers' reactions to paternalistic food policies by placing the seller at the center of the analysis. I use models of nonlinear pricing to derive hypotheses, which I test in controlled laboratory experiments. In the first two essays I explore the economic impacts of taxes and portion cap rules when single-product sellers serve privately informed buyers. In the third, I examine the economic effects of portion cap rules when two-product sellers serve buyers with private preferences.

In the first essay, collective work with Dr. Joseph Balagtas and Dr. Steven Wu, I compare the impacts of taxes and portion control rules on profit and consumer surplus. I model the pricing problem of a single-product seller serving two types of privately-informed customers. I aim to answer the following questions: i) what effects do taxes have on portion sizes, buyer surplus, and seller's expected profit; ii) how does the tax affect the seller's ability to screen the market, and iii) how the effects of taxes and portion cap rules compare. I find that under a tax regime, all package sizes are smaller; high willingness to pay buyers see a reduction in their surplus, and the

retailer's expected profit is unambiguously diminished. Both policy instruments curb consumption. In contrast with tax regimes, however, cap rules leave buyer surplus unaffected. These outcomes suggest that portion control rules might be a preferred over tax regimes as methods to regulate consumption of calorie-dense and low-nutrient foods traded in settings where retailers engage in second-degree price discrimination.

In the second paper, also joint work with Dr. Joseph Balagtas and Dr. Steven Wu, I report a controlled laboratory experiment designed to test the results of my first essay. In this project, human subjects take on the role of sellers and are free to decide their pricing strategies, including number of "packages", their price and their quantity. We vary the policy environment across treatments,and these include: unregulated baseline, cap rule, and specific tax. My principal goal is to test the theoretical outcomes of the first essay and find which regulation is associated with a smaller negative impact on consumers' economic surplus in the laboratory. My main finding is that the cap does not impact buyers' information rents regardless of the seller's segmentation scheme; while the effect of the tax is contingent on the seller's strategy and is neutral at best.

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

1. INTRODUCTION

I study how price-discriminating sellers decide their pricing schemes under different policy environments. I am especially interested in the impacts that these interventions have on quantities purchased and consumer surplus. The motivation for my research comes from food policy; specifically from two instruments designed to combat obesity via food retailing regulations: taxes and portion cap rules (limits on the maximum default size in which a product can be offered). I concentrate my analysis on the sellers' reaction to these policies by leveraging nonlinear pricing theory. My empirical work relies on controlled economic experiments. The research in this dissertation is relevant for two reasons: firstly, the study of regulations of food retailing is timely as obesity rates in the United States hover over 30% [1] and pressure to implement consumption-curbing policies grows; secondly, focusing on how sellers adjust their pricing behavior, as opposed to how buyers respond to the measures, is a novel approach within the food policy evaluation literature which can complement existing studies in the area of food retailing regulation.

In the United States, dead-weight losses of over $148 billion dollar are attributable to obesity and its health consequences [2]. Expenses associated with treatments of obesity-related diseases as a proportion of national health expenditures are estimated to be between 9.1% and 20.6% [3] [4]. These facts put obesity among the most pressing public health issues facing the country. To cope with this situation, policy makers and sectors of the academic community have proposed to enact policies to regulate food retailing. Their goal is to reduce the consumption of foods and ingredients associated with obesity. Among the most noticeable publications promoting the regulation of retail of harmful foods are a recent *Nature* article titled "The toxic truth about sugar" and a World Health Organization report named "Fiscal policies for diet and the prevention of noncommunicable diseases" [5] [6]. Sugar-sweetened beverages (SSB)

are frequent targets of policy interventions. Since 2014 when the first so-called "soda tax" was approved in the city of Berkeley California, several localities within the U.S. have sought to implement their own tax on sales of SSB. As of March 2018, the list of localities with approved local taxes on SSB include Albany, CA; Berkeley, CA; Boulder, CO; Oakland, CA; Philadelphia, PA; San Francisco, CA; and Seattle, WA. Portion cap rules are measures that impose a limit on the maximum default size a food can be offered for sale. Cap rules are an alternative to taxes. Compared to excise taxes, these measures have been less studied. In this dissertation, I address the paucity of economic research on portion cap rules and their effects on sellers' pricing behavior.

The focus on seller's pricing behavior is a novel characteristic of my research. Most of the literature looking at the impacts of either taxes or portion cap rules that I cite throughout this dissertation centers on how buyers react to the interventions. These studies however assume that sellers adopt a passive pricing strategy. To have a more complete image of the impacts of these policies, a detailed examination of how sellers change their strategies to accommodate the interventions is needed. This is because, ultimately, food retailers design the menus from which buyers choose their consumption. My research tackles this need.

In the first two essays, I compare the economic impacts of taxes and portion cap rules in single-product markets where buyers have private information regarding their preferences. I use a single-product nonlinear pricing model to derive hypotheses which I then test in an economic laboratory experiment. I find that moderate caps successfully reduce consumption without impacting the well-being of buyers. In the third essay, I aim to learn whether these results extend to the multidimensional case. In this essay, I concentrate on studying pricing schemes by sellers that offer two products (A and B) and practice commodity bundling. I ask the following questions: If we were to enforce a cap rule on one of the foods (say A), what would be the impacts on i) offered sizes of the regulated food A, ii) offered quantities of the unregulated product B, and iii) consumer welfare. I use a bi-dimensional nonlinear pricing model

to derive my hypotheses, Which I test in the laboratory. At the baseline, the seller offers small-small, medium-large, large-medium, and large-large soda-fries combos. Looking at the experimental data, I find that a regulation limiting the size of A to be no larger than the medium unregulated option produces the following impacts: i) smaller options of A for all buyers; ii) No significant changes in portions of B, and surprisingly, iii) a subset of buyers are better-off and none of them are worse-off. It is important to highlight that I look at the impact of the regulation with the most neutral background possible. In my model, deleterious impacts of consuming either of the products are absent. Thus, welfare improvements do not stem from limiting consumption of a harmful product. At the same time, the items are neither complements nor substitutes, this means that welfare increments are not explained by consumers being forced to buy two substitutes in the baseline. All changes are due to the multidimensional nature of the incentive-design problem faced by the seller and her desire to segment demand. To put it simply, I am showing that a portion cap rule changes allocation and rents even when the products have nothing to do with each other.

2. PORTION RESTRICTIONS VERSUS TAXES FOR REGULATION OF SUGAR-SWEETENED BEVERAGES

2.1 Introduction

Increased public awareness of the negative impacts of obesity has driven interest in public polices aimed at addressing obesity and its associated costs. Sugar consumption has been linked to increased risk of obesity and there is a growing, if still fluid, body of evidence that added sugars in sugar-sweetened beverages (SSBs) are uniquely harmful [7] [8] [9].[1] SSBs are low in satiety, have minimal nutritional value, and comprise a large portion of the added sugars in the American diet [12]. Thus much of the public policy debate surrounding obesity has focused on reducing consumption of SSBs. For example, Lustig and co-authors (2012) [5] advocate for restrictions on sales of sugary foods using a public health argument that draws a parallel between sugar and tobacco and alcohol, and the World Health Organization (WHO) calls for taxes on SSBs as means to reduce sugar consumption to levels recommended by the institution's guidelines [13].[2]

In this paper, we consider the economic effects of two alternative policy interventions: taxes and portion cap rules (limits of the maximum default size in which an SSB can be offered). We focus on these regulations because taxes, especially per-unit excise taxes, are the focus of the majority of scholarly work on economic policies targeting consumption of drinks with added sugar; size caps are a relatively straightforward and easy-to-implement alternative that nonetheless are highly polemic. Moreover,

[1]Most definitions of sugar-sweetened beverages (SSB) are based on the criteria of "added sugars" and include, energy, sport, and regular soft drinks, among others [10]. The category of "added sugars" does not include naturally-occurring sugars included in the broader group of "free sugars". The former are added into the beverage mix during the preparation process, while the later includes added sugars plus sugars naturally present in the beverage itself or in its ingredients [11].

[2]The WHO recommends an intake of free-sugars equivalent to less than 10 percent of total energy intake [14].

there is a lack of economic analysis, both theoretical or empirical, on the impact of portion cap rules, making it difficult to weigh the benefits and costs of taxes versus portion size restrictions.

Soda taxes have recently been passed in Berkeley, CA, Philadelphia, PA, Mexico, and elsewhere [15] [16] [17]. While taxes forge ahead, there is only limited evidence that such policies effectively reduce consumption, and virtually no evidence of their broader economic effects. To date, research has focused on measuring the short-term effects of soda taxes on prices and consumption from recent policy experiments both in the U.S. and abroad. These studies suggest that taxes have caused higher prices and reduced consumption of taxed beverages [18] [19] [20] [21] [22]. There are remaining open questions on the long-term effects of such taxes on prices, consumption, and consumer welfare.

Portion size restrictions have been less prevalent in practice. In 2013 Mayor Bloomberg of New York City proposed a rule prohibiting the sale of SSBs in cups exceeding 16 ounces, but the rule was later struck down in court [23]. Nonetheless, analyzing this policy still has some relevance since the state of Mississippi passed a bill in 2013 that has been called the "anti-Bloomberg bill" [24]. The bill was passed ostensibly to protect consumer welfare from government interference of personal consumption choices. Moreover, size caps are still viable policy instruments given their simplicity. In fact, a McKinsey Global Institute report considers portion control schemes as the most cost-effective method for abatement of obesity [25].

In contrast to much of the extant literature, we consider soda-consumption policies in a framework that allows sellers (food manufacturers and/or retailers) to adjust their strategic pricing schemes in order to accommodate the exogenous interventions while pursuing profit-maximization. In food markets characterized by branding and concentration, sellers exert market power and have the incentive to react to market interventions. Such responses could include not only price pass-through but also discrete changes in the nonlinear pricing structure typically used by soft-drink vendors. The economic effects of interventions in markets where sellers design their menus

strategically are not easy to discern directly. Thus, an important contribution of our investigation is its focus on the retailer's strategic reaction to the policy.

We posit a model of a trading situation wherein a seller faces consumers that hold private information about their taste for the good. As a consequence of asymmetric information, the seller engages in a screening strategy in the form of nonlinear pricing. By accounting for endogenous menu design strategies, we illuminate the underlying mechanism behind the potential distributional consequences of alternative marketing regulations.

Our analysis yields important, new insights relevant to the public debate over SSB policies or similar policies implemented in food markets where sellers may respond strategically to market interventions. A key finding is that while both taxes and portion cap regulations reduce SSB consumption, they have very different consequences for prices and economic welfare. Portion caps achieve reduced consumption without reducing consumer surplus of heavy soda drinkers, since sellers lower the price of affected products in order to segment the market. This is particularly important in a debate where consumer advocates are concerned about the regressiveness of soda taxes.[3]

2.2 Prior Relevant Literature

Our work complements the growing economic and public health literature analyzing the consequences of either restraining default portions or taxing consumption of beverages with added sugars. These studies typically look at either consumer's reaction to the policy or at responses at the retail price level, taking the seller's decisions as given. We emphasize the role of the seller, since she decides the characteristics of the menu before and after an intervention. By using a nonlinear pricing framework, our paper provides a more complete explanation of the mechanisms behind changes in the variables of interest.

[3]Because consumption of sugary drinks in relation to overall diet is higher among low-income consumers, soda taxes are deemed to be potentially regressive [26]

The work by Bourquard and Wu [27] is close in spirit to our analysis. Bourquard and Wu analyze portion size restrictions with the same nonlinear pricing framework we use in this document. Their model includes a price-discriminating seller facing demand form a buyer with two potential willingness to pay for soda. They conclude that portion caps do reduce cup sizes and, as long as the allowed maximum size is larger than or equal to the smaller container offered under no regulation, consumer surplus remains unaffected. This is because adverse selection provides a strong incentive for the seller to adjust post-regulation prices down. We extend this study by examining the impact of SSB taxes and then compare the economic effects of taxes and quantity caps.

Wilson, Stolarz-Fantino, and Fantino [28] (hereafter WSF) conduct a behavioral study aiming to determine how restrictions in cup sizes might affect final SSB consumption. In a non-incentive-compatible experiment, human subjects are asked to declare hypothetical purchases. Two menus are offered, one where a the largest cup had a capacity of 32oz, and a second menu where the largest cup is replaced for 16oz cups. The authors assume that, in the constrained case, the retailer offers as many smaller cups as possible so as to maintain consumed amounts constant. Their key finding is that subjects presented with the restricted menu end up buying more soda. Although the framing effect identified by this study is potentially important, economic analysis grounded in second-degree price discrimination adds additional insights. WSF result may suggest that sellers could increase amounts sold implementing the costless strategy of offering small cups only. This is counterintuitive, since in practice most food retailers do offer differentiated price-quantity options in their menus. John, Donnelly, and Roberto [29] (henceforth JDR) conducted a behavioral study with human subjects similar to that of WSF, but including incentive-compatibility via priced menu options and a budget constraint. Still concentrating on the demand side of the market, JDR find that a restricted menu does reduce consumption of soda. JDR also find that free-refills are associated with larger soda intake and this effect is stronger when refills are served by waiters.

Our approach of leveraging nonlinear pricing theory in order to put emphasis on how a seller changes her endogenous pricing strategies following an exogenous intervention is not commonly used in the food policy evaluation literature. This is an important feature in our analysis because enforcing rules that ignore pricing behavior may result in unwanted unintended consequences. Bonnet and Réquillart (2013) [30] highlight the importance of taking strategic pricing of manufacturers and final sellers into account when evaluating food policy. Using French representative consumer panel data, these authors used structural econometric models and policy simulations to evaluate the incidence levels of ad valorem and per-unit taxes on soft drinks. They modeled demand to incorporate consumer substitution, and supply in such manner that manufacturers and retailers use nonlinear pricing in their vertical interactions. They find that strategic firms react differently to distinct tax regimes; per-unit taxes are overshifted to final prices while ad valorem taxes are undershifted. Bonnet and Réquillart conclude that an incorrect assumption of passive pricing would lead to an underestimating (overestimating) the effects on consumption of an ad valorem (specific) tax. While Bonnet and Réquillart focused on strategic relationships between soda manufacturers and retailers, we are interested on isolating the effects of taxes due to strategic interactions between the retailers and final consumers.

A large number of empirical studies have estimated the very short-term effects on consumption following a soda-tax implementation. For example, using data from a nationally representative survey, Fletcher, Frisvold E and Tefft (2010) studied SSB taxation using variation of tax rates across states and time in order to identify the effects on consumption by adolescents and children [31]; they found a negative impact on consumption of SSB, but the effect was offset due to substitution of other calorie dense beverages. Falbe *et al* (2016) [19] use self-reported data to learn the past-tax impact on SSB consumption in Berkeley, California. They find a significant decline in self-declared levels of consumption. Grogger (2017) studied the case of the Mexican per-unit tax on SSB [20]. He found evidence of over-shifting on prices of beverages with added sugars, and less evidence of an increase in prices of other calorie dense

drinks. He interprets this as a likely indication of lower caloric intake via SSB in the typical Mexican diet, which could result in a reduction in mean body mass. These studies concentrate on buyers' reaction to the policy and taxes' pass-through. Open questions remain regarding the seller's reaction to the policy.

2.3 Model Setup Without Regulations in Effect

We begin by establishing an unregulated benchmark for the retailer's pricing behavior in the absence of regulation. This will allow us to make subsequent comparisons with respect to the impact of regulation on cup size, expected profit and consumer surplus. Our model is a fairly standard nonlinear pricing model where the seller (the principal) offers a menu of take-it-or-leave-it contracts with different price-size combinations of the same divisible good to a privately informed buyer (the agent). The seller faces uncertainty in one dimension: she cannot observe buyers' preferences (or taste). However, she does know the distribution of buyer types in the population she serves. There are two types of buyers in the market. High type (H-types) customers have a high willingness to pay for the good and consume larger quantities of it. Low type (L-types) buyers have a low willingness to pay and are less inclined to purchase large portions.[4] The seller is risk neutral and has full commitment power.

Let q represent cup size (e.g. number of ounces contained in the cup).[5] The seller's production cost is $c(q)$. We assume $c(q) = cq$ where $c'(q) = c > 0$ is a positive constant. The profit obtained by the seller after selling a cup with non-negative quantity q to an i-type buyer is $t(q_i) - cq_i$, where $t(q_i)$ is the price the buyer pays for q_i units of the good. For notational convenience, let $t_i = t(q_i)$ be the price per serving, so that if p_i is the per-unit (e.g. per-ounce) price, $t_i = p_i \cdot q_i$.

[4] Adding more than two-types to our model would only complicate the analysis, and reduce clarity and intuition without altering the general qualitative conclusions. Continuous type models would overmodel the way SSBs are typically sold which is only in a few sizes. Even adding one additional type would not alter the main qualitative conclusions as pointed out by Bourquard and Wu (2016) [27].

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

There is a fraction $\beta \in [0,1]$ of Low-types. The i-type buyer's surplus is $U_i = \theta_i v(q_i) - t_i$, for $i = H, L$. The taste parameter θ_i characterizes the i-type buyer's valuation for the good. $\theta_H > \theta_L$, so that the Spence-Mirrlees single crossing condition is satisfied. We assume that $v(0) = 0$, $v'(q) > 0$ and $v''(q) < 0 \; \forall \; q \geq 0$. Additionally, we suppose that $\theta_H v'(0) > c$ and $\lim_{q\to\infty} \theta_H v'(q) < c$, so that at least H-type consumers have an incentive to engage in trade, and the retailer offers only finite quantities. We require voluntary participation at the interim level. Both parties have a reservation value of zero.

By the revelation principle [32], we can state that the expected profit maximizing seller implements an incentive-compatible and individually rational direct mechanism. Bearing in mind that t_i represents the price paid for one serving (say, for a cup of soda) as opposed to price per unit (e.g. per ounce), the seller's problem is to maximize her expected profit subject to traditional set of incentive-compatibility (IC) and individual-rationality (IR) constraints:

$$
\begin{aligned}
&\underset{(t_L,q_L),(t_H,q_H)}{\text{maximize}} \quad \mathbb{E}\left[\pi\right] = (\beta)[t_L - cq_L] + (1-\beta)[t_H - cq_H] \\
&\text{subject to:} \\
&\text{ICH} : \theta_H v(q_H) - t_H \geq \theta_H v(q_L) - t_L \\
&\text{ICL} : \theta_L v(q_L) - t_L \geq \theta_L v(q_H) - t_H \\
&\text{IRH} : \theta_H v(q_H) - t_H \geq \bar{v_H} \\
&\text{IRL} : \theta_L v(q_L) - t_L \geq \bar{v_L}
\end{aligned}
\tag{2.1}
$$

Where $\bar{v_i}$ is the i-type's reservation utility. Without loss of generality, we let $\bar{v_i} = 0$. From this set of self-selection and participation restrictions, and the fact that marginal utility of consumption increases with the taste parameter θ_i, we can conclude that IRH and ICL will not bind at the optimum and can be omitted from the optimization program.

At the optimum, the relevant participation and incentive-compatibility constraints bind with equality and can be used to obtain the following pricing rules:

$$t_L = \theta_L v(q_L) \tag{2.2}$$

$$t_H = \theta_H v(q_H) - (\theta_H - \theta_L) v(q_L) \tag{2.3}$$

Substituting (2.2) and (2.3) into the objective function, we can re-express the original program as an unrestricted maximization problem:

$$\max_{q_L, q_H} \quad \mathbb{E}[\pi] = \beta[\theta_L v(q_L) - c q_L] + (1-\beta)[\theta_H v(q_H) - (\theta_H - \theta_L) v(q_L) - c q_H] \tag{2.4}$$

The quantities in square brackets in (2.4) are "virtual surpluses" generated by transactions between the Soda retailer and an i-type consumer. When the seller and an L-type buyer engage in transaction, virtual surplus equals actual surplus.[6] On the other hand, the virtual surplus generated by a transaction with an H-type consumer is smaller than the actual surplus due to the information rents the seller grants to the buyer in order to induce truthful revelation of type. The first order Kuhn-Tucker conditions of this problem are:

$$\begin{aligned} &\text{FOC}[q_H] : \frac{\partial \mathbb{E}[\pi]}{\partial q_H} = (1-\beta)[\theta_H v'(q_H) - c] \leq 0 \\ &\text{where} \\ &q_H \geq 0 \quad \text{and} \quad \frac{\partial \mathbb{E}[\pi]}{\partial q_H} \cdot q_H = 0 \end{aligned} \tag{2.5}$$

[6]The "actual surplus" generated by a transaction with an i-type consumer equals the buyer's utility of consuming quantity q minus the retailer's cost of selling quantity q: actual surplus $= \theta_i v(q) - c(q)$.

$$\text{FOC}[q_L] : \frac{\partial \mathbb{E}[\pi]}{\partial q_L} = \beta[\theta_L v'(q_L) - c] + (1-\beta)[-(\theta_H - \theta_L)v'(q_L)] \leq 0$$

$$\text{where} \tag{2.6}$$

$$q_L \geq 0 \;\text{ and }\; \frac{\partial \mathbb{E}[\pi]}{\partial q_L} \cdot q_L = 0$$

We assume that the soda retailer can implement one of the following three marketing schemes. She can either i) adopt a "separating" strategy: offer two differentiated price-size combinations intended to serve each type of buyer, ii) implement an "exclusive" scheme: concentrate on serving H-type buyers exclusively or iii) apply a "pooling" or one-size-fits-all strategy: attempt to cover the entire demand with a single price-size combo. Below, we present each of these pricing schemes' implications for size, consumer surplus and producer's expected benefit. We will refer to them as unregulated cases I-A, I-B, and I-C, respectively.

2.3.1 Unregulated Case I-A: The seller serves both types of consumers

The soda retailer offers a menu of two cup sizes with distinct price-size combinations with strictly positive quantities $q_H > 0$ and $q_L > 0$. First Order Conditions FOC$[q_H]$ and FOC$[q_L]$ in (2.5) and (2.6) bind with strict equality. This implies:

$$\theta_H v'(q_H) = c \tag{2.7}$$

$$\theta_L v'(q_L) = c + \left(\frac{1-\beta}{\beta}\right)(\theta_H - \theta_L)v'(q_L) \tag{2.8}$$

It follows from (2.7) that there is no distortion at the top. The large cup contains a quantity of product that guarantees efficient consumption. The amount of product contained in the large cup equates H-type's marginal utility of consumption with the seller's marginal cost of production.

On the other hand, the small cup contains a quantity of product lower than the L-type buyer's first best. For the seller, it is more costly to serve an L-type consumer since on top of marginal cost of production, she incurs in an additional cost $\left(\frac{1-\beta}{\beta}\right)(\theta_H - \theta_L)v'(q_L)$, associated with the information rent transferred to high types. The soda retailer distorts the quantity supplied downwards and equates marginal cost to virtual marginal benefit to the consumer:

$$v'(q_L)\left[\theta_L - \left(\frac{1-\beta}{\beta}\right)(\theta_H - \theta_L)\right] = c \tag{2.9}$$

Let $q_L^{ia} > 0$ and $q_H^{ia} > 0$ be the quantities that solve (2.7) and (2.9). If it exists, the unique interior solution to this problem is characterized by equations (2.10) and (2.11). These imply $q_L^{ia} < q_H^{ia}$. Therefore, the ICH restriction in the original problem (2.1) is satisfied.

$$\theta_H v'(q_H^{ia}) = c \tag{2.10}$$

$$\theta_L v'(q_L^{ia}) = \frac{c}{\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right]} > c \tag{2.11}$$

Final pricing rules are $t_H^{ia} = \theta_H v(q_H^{ia}) - (\theta_H - \theta_L)v(q_L^{ia})$ and $t_L^{ia} = \theta_L v(q_L^{ia})$. The retailer's expected profit is:

$$\pi^{ia} = (\beta)[\theta_L v(q_L^{ia}) - cq_L^{ia}] + (1-\beta)[\theta_H v(q_H^{ia}) - (\theta_H - \theta_L)v(q_L^{ia}) - cq_H^{ia}] \tag{2.12}$$

These results are summarized in proposition 2.3.1.

Proposition 2.3.1 *Suppose that the Soda retailer decides to screen the market by offering a menu of two price-size combinations. Assume the sale of the product is unregulated. Then:*

1. $\theta_H v'(q_H^{ia}) = c$ *So that H-types are offered a cup which size equals their first-best quantity.*

2. $\theta_L v'(q_L^{ia}) = \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]} > c$ *So that L-types are offered a package which size is less than their first-best quantity.*

3. $t_H^{ia} = \theta_H v(q_H^{ia}) - (\theta_H - \theta_L)v(q_L^{ia})$ *So that the price of the H-type package is discounted by an information rent.*

4. $t_L^{ia} = \theta_L v(q_L^{ia})$. *The retailer extracts all of the surplus from Low type buyers.*

5. *The seller's value optimized profit is expressed in equation (2.12).*

6. *The H-type consumer's value function is* $U_H^{ia} = (\theta_H - \theta_L)v(q_L^{ia})$.

7. *The L-type consumer's value function is* $U_L^{ia} = 0$.

Under no regulation, the second-degree price discriminating soda retailer will offer two differentiated price-size options for the buyer to decide on. The seller expects self-selection. Low willingness to pay customers are offered a small cup at the maximum per-unit price they are willing to pay for the product, thus they are indifferent between buying the cup or choosing a free outside option (e.g. a free of charge cup of water). High-willingness to pay buyers get to preserve some surplus, i.e. they are offered a large cup with a per-unit price smaller from the maximum they are willing to pay. The quantity discount granted by the retailer to those customers buying the large cup generates a consumption inefficiency: the small cup size is not enough so as to equate the L-type's marginal utility of consumption to its marginal cost of production.

Stylized observations from the fast food and food retail industries tell us that these are not common pricing schemes. Therefore, we will assume that, in an unregulated environment, retailers offer the separating strategy described above. However, there is no guarantee that the seller will continue with the segmentation strategy following either a tax or portion size regulation. Hence, we also describe the cases in which the retailer does not segment the market.

2.3.2 Unregulated Case I-B: The seller serves high type buyers exclusively

In this scenario, $q_H > 0$ and $q_L = 0$. Let the superscript ib denote variables that maximize the retailer's benefit under this strategy and policy environment. Using FOC$[q_H]$ from (2.5), and pricing rule (2.3) we obtain:

$$\theta_H v'(q_H^{ib}) = c \tag{2.13}$$

$$t_H^{ib} = \theta_H v(q_H^{ib}) \tag{2.14}$$

The per-serving price is higher because the seller no longer needs to elicit truthful revelation of private information and therefore does not need to grant information rents. Both consumer types are held at their reservation values. Expected profit is in equation (2.15). These results are summarized in proposition 2.3.2.

$$\pi^{ib} = (1 - \beta)[\theta_H v(q_H^{ib}) - cq_H^{ib}] \tag{2.15}$$

Proposition 2.3.2 *Suppose that the Soda retailer decides to serve high willingness to pay consumers exclusively. Assume the sale of the product is unregulated. Then:*

1. $\theta_H v'(q_H^{ib}) = c$ *So that H-types are offered a cup which size equals their first-best quantity.*

2. $t_H^{ib} = \theta_H v(q_H^{ib})$ *So that the retailer extracts all of the surplus from high type buyers.*

3. *The seller's value optimized profit is expressed in equation (2.15).*

4. *The H-type consumer's value function is* $U_H^{ib} = 0$.

5. *The L-type consumer's value function is* $U_L^{ia} = 0$.

2.3.3 Unregulated Case I-C: One-Size-Fits-All

The retailer could ignore buyers' taste discrepancies. In this case, the seller pools the market; i.e. she stops customizing prize-size bundles and implements a one-size-fits-all scheme. This implies that only one cup with size $q_L > 0$ is offered by the seller. The cup is designed so as to be purchased by any buyer regardless of his type. The retailer does not need to motivate revelation of private information from the high type buyers; she only needs to assure participation of clients with low willingness to pay. Her optimization problem can be written as follows:

$$\begin{aligned} &\max_{t,q} \ \mathbb{E}[\pi] = t_L - cq_L \\ &\text{subject to:} \\ &\text{PCL} : \theta_L v(q_L) - t_L \geq \bar{v}_L \end{aligned} \tag{2.16}$$

Since the Spence-Mirrlees single crossing condition is satisfied, low types engaging in transactions imply participation of high types. Without loss of generality, we let $\bar{v}_L = 0$ Profit maximization in this case implies:

$$\theta_L v'(q_L^{ic}) = c \tag{2.17}$$

$$t_L^{ic} = \theta_L v(q_L^{ic}) \tag{2.18}$$

Thus, L-type consumers do get their first best quantity. The retailer's expected benefits are in (2.19) and the clients' value functions in (2.20).

$$\pi^{iic} = \theta_L v(q_L^{ic}) - cq_L^{ic} \tag{2.19}$$

$$\begin{aligned} U_L^{ic} &= 0 \\ U_H^{ic} &= (\theta_H - \theta_L) v(q_L^{ic}) \end{aligned} \tag{2.20}$$

Proposition 2.3.3 *Suppose that the Soda retailer decides to pool the demand and implement a one-size-fits-all marketing scheme. Assume the sale of the product is unregulated. Then:*

1. $\theta_L v'(q_L^{ic}) = c$ *So that L-types are offered a cup which size equals their first-best quantity.*
2. $t_L^{ic} = \theta_H v(q_L^{ic})$ *So that the retailer extracts all of the surplus from low type buyers.*
3. *The seller's value optimized profit is expressed in equation (2.19).*
4. *The H-type consumer's value function is* $U_H^{ic} = (\theta_H - \theta_L)v(q_L^{ic})$.
5. *The L-type consumer's value function is* $U_L^{ic} = 0$.

2.4 Incorporating Taxation into the Model

We expect the tax on soda to have two major effects, it will impact final cup sizes and prices, and it may cause the retailer to alter her marketing strategy. We start by analyzing the direct effects of the tax on sizes and prices *holding the seller's pricing strategy constant.*

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. In order to avoid divisions by zero later on, we excluded combinations where $\tau_v = 1$. We do not include the singleton $(\tau_s, \tau_v) = (0, 0)$ since it represents the event of no taxation discussed in the previous section. When a tax regime is in effect, the seller's problem is:

$$\max_{q_L, q_H} \ \mathbb{E}[\pi] = (1-\tau_v)\Big\{(\beta)\Big[\theta_L v(q_L) - \Psi_L\Big] + (1-\beta)\Big[\theta_H v(q_H) - (\theta_H - \theta_L)v(q_L) - \Psi_H\Big]\Big\} \tag{2.21}$$

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

$$\begin{aligned}
&\text{FOC}[q_H] : \frac{\partial \mathbb{E}[\pi]}{\partial q_H} = (1-\tau_v)(1-\beta)[\theta_H v'(q_H) - \psi] \leq 0 \\
&\text{where} \\
&q_H \geq 0 \;\text{ and }\; \frac{\partial \mathbb{E}[\pi]}{\partial q_H} \cdot q_H = 0
\end{aligned} \tag{2.22}$$

$$\begin{aligned}
&\text{FOC}[q_L] : \frac{\partial \mathbb{E}[\pi]}{\partial q_L} = (1-\tau_v)\Big\{\beta(\theta_L v'(q_L) - \psi) + (1-\beta)[-(\theta_H - \theta_L)v'(q_L)]\Big\} \leq 0 \\
&\text{where} \\
&q_L \geq 0 \;\text{ and }\; \frac{\partial \mathbb{E}[\pi]}{\partial q_L} \cdot q_L = 0
\end{aligned} \tag{2.23}$$

Specific taxes modify the objective function in a way akin to a change in the principal's cost function. Ad valorem taxes alter the objective function in two manners: by modifying the cost function, and scaling down expected profit. Because profit decreases with cost, virtual surpluses are smaller compared to problem (2.4). This claim is easy to verify.

***Claim** 1. When a tax regime (τ_s, τ_v) is in effect and the seller's objective function is (2.21), virtual surpluses are strictly smaller compared to the virtual surpluses when there is not a tax regime in effect and the retailer's objective function is (2.4).*

Proof *We show that this claim is valid for virtual surplus generated by transaction between the principal and an H-type agent. The case for principal - L-type agent transaction can be demonstrated in an identical manner.*

Assume that the virtual surplus under tax regime (τ_s, τ_v) is larger than or equal to the virtual surplus generated when no tax regime is in effect. This would imply:

$$\begin{aligned}
&\theta_H v(q_H) - (\theta_H - \theta_L)v(q_L) - cq_H \leq \theta_H v(q_H) - (\theta_H - \theta_L)v(q_L) - \Psi_H \\
&cq_H \geq \Psi_H = \left(\frac{\tau_s q_H + cq_H}{1-\tau_v}\right) \\
&c \geq \psi = \left(\frac{\tau_s + c}{1-\tau_v}\right)
\end{aligned}$$

The effective marginal cost of production ψ *takes arguments* $(\tau_s, \tau_v) \in \mathrm{T}$ *from domain* $\mathrm{T} = \Big\{[0,1] \times [0,1)\Big\} \setminus (0,0)$.

Since $c > 0$*, the only case when the inequality above is true is when* $(\tau_s, \tau_v) = (0,0) \notin \mathrm{T}$*, i.e. when there is no active tax regime.*
$\therefore \forall\, (\tau_s,\, \tau_v)$ *is true that* $\left(\frac{\tau_s + c}{1 - \tau_v}\right) > c$*. Thus, virtual surplus under tax regime* $(\tau_s,\, \tau_v)$ *is strictly smaller compared to the unregulated case.* ■

Below, we describe the effects directly attributable to taxation *holding the seller's marketing strategy constant*. Recall that we previously derived benchmark results for three possible marketing schemes, namely when the retailer either i) designs a nonlinear price schedule in order to price discriminate, ii) targets high type buyers exclusively or iii) serves all customers with a single price-size combination. We compare the effects of taxes on each of these marketing schemes and compare them with their corresponding counterfactual unregulated scenario.

2.4.1 Taxed Case II-A: The Seller Serves Both Types of Consumers

The menu of contracts features strictly positive quantities q_H and q_L. Both first order conditions in (2.22) and (2.23) hold with strict equality, implying:

$$\theta_H v'(q_H) = \psi \tag{2.24}$$

$$\theta_L v'(q_L) = \psi + \left(\frac{1-\beta}{\beta}\right)(\theta_H - \theta_L) v'(q_L) \tag{2.25}$$

The retailer designs a menu of offers such that the effective marginal cost of producing a large cup equals the high-type buyer marginal utility of consumption. The seller distorts the size of the package downwards and equates effective marginal cost of producing the small cup to the virtual marginal benefit that the L-type consumer obtains after the purchase:

$$\theta_L v'(q_L)\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]=\psi \tag{2.26}$$

Let $q_L^{iia}>0$ and $q_H^{iia}>0$ be the quantities that solve (2.24) and (2.25). If it exists, the unique interior solution is characterized by (2.27), and 2.28. These imply $q_H^{iia}>q_L^{iia}$.

$$\theta_H v'(q_H^{iia})=\psi \tag{2.27}$$

$$\theta_L v'(q_L^{iia})=\frac{\psi}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}>\psi \tag{2.28}$$

With a tax in effect, both types of consumers get less than their first-best optimal quantities because $\psi > c\ \forall(\tau_s,\tau_v)\in T$. The retailer's expected profit is smaller, compared to the unregulated case. Equation (2.27) suggests that under a tax regime, there is distortion at the top. L-types also receive a smaller quantity compared to the unregulated case I-A, which is already smaller than their first best. Two facts explain the decrease in size of the small cup: i) as in the unregulated scenario, the marginal cost of serving L-types is driven up by information rents transferred to clients who prefer to buy the large cup of soda, and ii) since $\psi > c$, the tax regime drives up the cost of serving all consumer, consequently, the seller offers smaller quantities across both screening contracts.

The price rules associated with this case are $t_L^{iia}=\theta_L v(q_L^{iia})$, and $t_H^{iia}=\theta_H v(q_H^{iia})-(\theta_H-\theta_L)v(q_L^{iia})$. The seller's expected profit is in equation (2.29).

$$\pi^{iia}=(1-t_v)\Big\{(\beta)[\theta_L v(q_L^{iia})-\psi q_L^{iia}]+(1-\beta)\Big\{[\theta_H v(q_H^{iia})-(\theta_H-\theta_L)v(q_L^{iia})]-\psi q_H^{iia}\Big\}\Big\} \tag{2.29}$$

In proposition 2.4.1, we compare the outcomes above with the results derived in our benchmark case I-A, where there is no marketing regulation and the seller price discriminates. We omit the proof since it is a straightforward comparison.

Proposition 2.4.1 *Assume 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 serve both type of buyers offering two tailored price-size combinations. Then:*

1. $\theta_H v'(q_H^{iia}) = \psi$. *There is distortion at the top, therefore* $q_H^{ia} > q_H^{iia}$.

2. $\theta_L v'(q_L^{iia}) = \frac{\psi}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]} > \psi$. *L-type consumers get a quantity lower than their first best. Moreover,* $q_L^{ia} > q_L^{iia}$.

3. $t_L^{iia} = \theta_L v(q_L^{iia})$. *So that* $t_L^{ia} > t_L^{iia}$.

4. $t_H^{iia} = \theta_H v(q_H^{iia}) - (\theta_H - \theta_L) v(q_L^{iia})$. *So that* $t_H^{ia} > t_H^{iia}$.

5. *The retailer's value function is (2.29), thus* $\mathbb{E}\,\pi^{ia} > \mathbb{E}\,\pi^{iia}$.

6. *H-type buyer's value function is* $U_H^{iia} = (\theta_H - \theta_L) v(q_L^{iia})$, *thus* $U_H^{ia} > U_H^{iia}$.

7. *L-type buyer's value function is* $U_L = 0$, *thus* $U_L^{ia} > U_L^{iia}$.

The size of both packages is smaller. The distortion introduced by the tax regime causes inefficiency in consumption. Neither cup being offered contains the first-best quantity for their intended customers. High willingness to pay consumers still receive information rents, although these are smaller. Low willingness to pay buyers are held at their reservation values, and the seller see her expected profit unambiguously diminished.

2.4.2 Taxed Case II-B: The Seller Serves only H-type consumers

The seller sets $q_H > 0$ and $q_L = 0$. Let the superscript iib denote variables that maximize the retailer's benefit under this strategy. This scheme implies that FOC$[q_L]$ in (2.23) does not bind with equality. Using FOC$[q_H]$ from (2.22), pricing rule (2.3), and our normalizing assumption $v(0) = 0$, we obtain:

$$\theta_H v'(q_H^{iib}) = \psi \tag{2.30}$$

$$t_H^{iib} = \theta_H v(q_H^{iib}) \tag{2.31}$$

The seller no longer needs to elicit truthful revelation of information and therefore does grant information rents. The quantity offered to H-types under this marketing strategy is smaller compared to the quantity offered in our benchmark unregulated case I-B. Low type buyers are excluded from trade and high type consumers are held at their reservation values. Expected profit is in equation (2.32).

$$\pi^{iib} = (1 - \tau_v)(1 - \beta)[\theta_H v(q_H^{iib}) - \psi q_H^{iib}] \tag{2.32}$$

These results and comparisons with the base case I-B are summarized in proposition 2.4.2. The proofs are straightforward, so we do not include them.

Proposition 2.4.2 *Assume 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. $\theta_H v'(q_H^{iib}) = \psi > c$ *There is distortion at the top, therefore* $q_H^{iib} < q_H^{ib}$.
2. *L-type buyers are excluded and do not engage in trade.*
3. $t_H^{iib} < t_H^{ib}$ *so that the price of the H-type package is higher in case II-B compared to benchmark case I-B.*
4. *The seller's value functions is expressed by equation (2.32). Thus,* $\mathbb{E}\,\pi^{iib} < \mathbb{E}\,\pi^{iib}$
5. *Both buyer types are held at their reservation values, this is* $U_H = U_L = 0$.

Following the implementation of a tax regime, if the SSB retailer decides to serve only customers with high preference for the product, then compared to the unregulated benchmark case I-B: the serving size is smaller and its price lower; neither type of buyer gets to retain consumer surplus, and expected profit decreases.

2.4.3 Taxed Case II-C: One-Size-Fits-All

If the retailer decides to ignore potential taste discrepancies, then she does not need to design an incentive-compatible menu of options. Her optimization problem can be written as follows:

$$\begin{aligned} &\max_{p,q} \ \mathbb{E}\left[\pi\right] = (1-\tau_v)t_L - (\tau_s + c)q_L \\ &\text{subject to:} \\ &\text{IRL} : \theta_L v(q) - t_L \geq 0 \end{aligned} \tag{2.33}$$

The seller designs a package that satisfies only the low type buyer's individual rationality constraint. Since $\theta_H > \theta_L$, this guarantees participation of high valuation buyers. Profit maximization implies:

$$\theta_L v'(q_L^{iic}) = \psi \tag{2.34}$$

$$t_L^{iic} = \theta_L v(q_L^{iic}) \tag{2.35}$$

Thus, the L-type consumers do not get their first best quantity. Let p_L^{iic} and q_L^{iic} be the optimal price and quantities. The retailer's expected benefits are in (2.36) and the clients' value functions in (2.37). We summarize the aforementioned results in proposition (2.4.3).

$$\pi^{iic} = (1-\tau_v)[\theta_L v(q_L^{iic}) - \psi \cdot q_L^{iic}] \tag{2.36}$$

$$\begin{aligned} U_L^{iic} &= 0 \\ U_H^{iic} &= (\theta_H - \theta_L)v(q_L^{iic}) \end{aligned} \tag{2.37}$$

These results and comparisons with the base case I-C are summarized in proposition 2.4.3. The proofs are straightforward, so we do not include them.

Proposition 2.4.3 *Assume the government enforces a tax regime* (τ_s, τ_v) *with at least one type of tax strictly positive. Suppose that the retailer decides not to screen the market and offers one size-price contract designed to serve both types of buyers. Then:*

1. $\theta_L v'(q_L^{iic}) = \psi$ *so that L-types are provided with a quantity smaller than their first best. Thus,* $q_L^{ic} > q_L^{iic}$ *therefore the serving size under taxation is smaller.*
2. *The price per serving is* $t_L^{iic} = \theta_L v(q_L^{iic})$*. Thus,* $t_L^{iic} < t_L^{ic}$
3. *The seller's value function is expressed by equation (2.36). Thus,* $\mathbb{E}\,\pi^{ic} > \mathbb{E}\,\pi^{iic}$.
4. *The L-type consumer value function is* $U_L^{iic} = 0$*. Thus,* $U_L^{ic} = U_L^{iic} = 0$
5. *The H-type consumer value function is* $U_H^{iic} = (\theta_H - \theta_L)v(q_L^{iic})$*. Thus* $U_H^{ic} > U_H^{iic}$.

Therefore, the size of the only cup for sale is not consumption-efficient for any type of buyer. The serving size is smaller compared to the unregulated case. Low willingness to pay buyers are left at their reservation value, while consumers with a high preference for the product get to retain some surplus, although this is smaller compared to the benchmark.

2.5 How does taxation affect retailers' choice of scheme?

Under no regulation, we expect the typical profit-maximizing soda retailer to screen the market by offering a menu of two different cups. Once the government decides to enforce a tax on sales of soda, the seller will re-calculate her expected profit if she were to continue business as usual, and contrast it with the benefits she would obtain if she were to implement a new pricing scheme. The seller will execute the strategy that would result in the highest economic benefit for her. We anticipate the seller to continue price discriminating and offering differentiated price-size combos. However, we cannot rule out a scenario where, as a result of the new policy, the retailer decides to switch her strategy altogether and start offering a single

cup. In this subsection, we derive the necessary conditions for the seller to shift her marketing scheme from taxed case II-A (Serve both types) to either strategy II-B (Serve H-type exclusively) or scheme II-C (one-size-fits-all).

First, we analyze the scenario where the seller changes her scheme from screening the market to serve H-type buyers exclusively. This shift would be beneficial if expected profit in case II-B is larger compared to expected benefit in case II-A ($\pi^{iib} > \pi^{iia}$). We make the following tie-breaking assumption: if $\pi^{iia} = \pi^{iib}$, then the retailer decides to keep offering two differentiated cups.

Proposition 2.5.1 *Suppose that a tax regime (τ_s, τ_v), comes into effect. Then, the seller will stop offering two price-size cups and she will exclusively serve H-type consumers only if the following inequality holds true:*

$$\theta_L v(q_L^{iia})\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right] < \psi q_L^{iia} \tag{2.38}$$

Proof *The proof is straightforward. We only need to find out under which condition $\mathbb{E}[\pi^{iia}]$ is smaller than $\mathbb{E}[\pi^{iib}]$:*

$$\pi^{iia} = (1-t_v)\Big\{(\beta)[\theta_L v(q_L^{iia}) - \psi q_L^{iia}] + (1-\beta)\Big\{[\theta_H v(q_H^{iia}) - (\theta_H - \theta_L)v(q_L^{iia})] - \psi q_H^{iia}\Big\}\Big\}$$

$$\pi^{iib} = (1-t_v)(1-\beta)[\theta_H v(q_H^{iib}) - \psi q_H^{iib}]$$

$$\pi^{iia} < \pi^{iib} \implies [\theta_L v(q_L^{iia}) - \psi q_L^{iia}] < \left(\frac{1-\beta}{\beta}\right)[(\theta_H - \theta_L)v(q_L^{iia})]$$

rearranging we get:

$$\theta_L v(q_L^{iia})\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right] < \psi q_L^{iia}$$

We use the fact that $\theta_H v'(q_H^{iia}) = \theta_H v'(q_H^{iib}) = \psi \implies q_H^{iia} = q_H^{iib}$. ■

Recall that when the retailer separates the market demand, she distorts quantity downwards and equates low type buyer's marginal benefit to marginal cost of production (from equation 2.26). The seller will start serving the high type buyer exclusively

if the market characteristics are such that the cost of producing the small cup is larger than the low type buyer's benefit of consumption. In other words, the retailer will move to an exclusive marketing strategy if the cost of producing the small cup that leaves the low type buyer at his reservation value is expensive enough so that the low type buyer would be better off choosing his outside option rather than engaging in trade.

We now turn to the case when the seller stops segmenting the market and engages in a one-size-fits-all strategy (taxed case II-C). This will occur if $\mathbb{E}[\pi^{iia}] < \mathbb{E}[\pi^{iic}]$. We make the tie-breaking assumption that if $\mathbb{E}[\pi^{iia}] = \mathbb{E}[\pi^{iic}]$, then the retailer decides to keep offering two differentiated price-size combinations. As expected, the conditions needed for this strategy to be the ideal for the retailer are rather stringent. Proposition 2.5.2 states a necessary condition for this strategy to be adopted by the retailer.

Proposition 2.5.2 *Suppose that a tax regime (τ_s, τ_v), comes into effect. Then, the seller will stop offering two price-size combinations and will start serving both types of consumers with a one-size-fits-all strategy only if the following inequality holds true:*

$$[\theta_L v(q_L^{iia}) - \psi q_L^{iia}] + \Big(\frac{1-\beta}{\beta}\Big)[\theta_H v(q_H^{iia}) - (\theta_H - \theta_L)v(q_L^{iia}) - \psi q_H^{iia}] < \theta_L v(q_L^{iic}) - \psi q_L^{iic} \tag{2.39}$$

Proof *The proof is straightforward. We only need to find out under which condition π^{iia} is lower than π^{iic}:*

$$\pi^{iia} = (1-t_v)\Big\{(\beta)[\theta_L v(q_L^{iia}) - \psi q_L^{iia}] + (1-\beta)\Big\{[\theta_H v(q_H^{iia}) - (\theta_H - \theta_L)v(q_L^{iia})] - \psi q_H^{iia}\Big\}\Big\}$$

$$\pi^{iic} = (1-t_v)[\theta_L v(q_L^{iic}) - \psi q_L^{iic}]$$

$$\pi^{iia} < \pi^{iic} \implies$$

$$\beta[\theta_L v(q_H^{iia}) - \psi q_L^{iia}] + (1-\beta)[\theta_H v(q_H^{iia}) - (\theta_H - \theta_L)v(q_L^{iia}) - \psi q_H^{iia}] < \theta_L v(q_L^{iic}) - \psi q_L^{iic}$$

■

Proposition (2.5.2) indicates that the retailer will stop tailoring price-size combos and will adopt a on-size-fits-all marketing approach if and only if the convex combination of the virtual surpluses obtained from the screening scheme is strictly smaller than the total virtual surplus gained under the pooling strategy.

Thus, the retailer will consider pooling the demand if the expected benefit of price discriminating is not worth the effort. Because the left hand side in equation 2.39 increases with β, the condition is more likely to hold true as the proportion of L-types decreases.

2.5.1 Effects on Quantities

We compare the size of the packages offered in the pre-tax scenario I-A to those in the taxed cases II-A, II-B and II-C. First we begin by contrasting the size of the large cups in the unregulated market (case I-A), versus the market-screening taxed setting (case II-A), and the scenario when the seller serves H-type exclusively (case II-B).

Proposition 2.5.3 *Suppose that a tax regime (τ_s, τ_v) is implemented. Then:*

- $q_H^{ia} > q_H^{iia}$
- $q_H^{iib} = q_H^{iia} \implies q_H^{ia} > q_H^{iib}$

Proof

From equations (2.10) and (2.27):

$\theta_H v'(q_H^{ia}) = c < \theta_H v'(q_H^{iia}) = \psi \implies q_H^{ia} > q_H^{iia}$

From equations (2.27) and (2.30):

$\theta_H v'(q_H^{iib}) = \theta_H v'(q_H^{iic}) = \psi \implies q_H^{iic} = q_H^{iic}$

■

The large cup offered without regulation is bigger compared to the large cup designed under taxation. This is true regardless of the marketing scheme (II-A or II-B) adopted by the seller.

We now move to analyze the effect on the small cup. We compare the size of the small package designed under no regulation (case I-A) versus the small cup offered in the market-screening taxed case (II-A), and the only package designed in the taxed one-size-fits-all scenario (II-C). The product quantity contained in the small cup in case I-A is unambiguously larger compared to the small package from case II-A. How large or small the cup designed under the taxed pooling strategy is relative to the small cup from case I-A depends on how harsh the tax regime is:

Proposition 2.5.4 *Suppose that a tax regime* (τ_s, τ_v)*, comes into effect. Then:*

1. If $\psi > \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, $q_L^{ia} > q_L^{iic} > q_L^{iia}$
2. If $\psi < \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, $q_L^{iic} > q_L^{ia} > q_L^{iia}$.
3. If $\psi = \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, $q_L^{ia} = q_L^{iic} > q_L^{iia}$.

Proof

From equations (2.11) and (2.28):

$$\theta_H v'(q_L^{ia}) = \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]} < \theta_L v'(q_L^{iia}) = \frac{\psi}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$$

which implies: $q_L^{ia} > q_L^{iia}$

From equations (2.11) and (2.34), $q_L^{ia} > q_L^{iic}$ if:

$$\theta_L v'(q_L^{ia}) = c + \Big(\frac{1-\beta}{\beta}\Big)(\theta_H - \theta_L)v'(q_L^{ia}) < \theta_L v'(q_L^{iic}) = \psi$$

which holds true is and only if:

$$\psi > c + \Big(\frac{1-\beta}{\beta}\Big)(\theta_H - \theta_L)v'(q_L^{ia})$$

From equations (2.28) and (2.34), it is easy to deduce that:

$q_L^{iic} > q_L^{iia}$

■

The retailer's effective marginal cost of production is ψ, while the number in the right hand side of the inequalities in proposition 2.5.4 is equal to the marginal utility of the L-type buyer in our benchmark case (see equation 2.11). The comparison between q_L^{iic} and q_L^{ia} depends on how high the effective marginal cost of production is relative to the marginal utility of the low type consumer in our benchmark case. For example, the size of the cup offered under the pooling strategy is smaller than the small cup in our benchmark case only if the tax regime causes the effective marginal cost of production to be larger than the expression $\frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$.

2.5.2 Effect of Taxation on Consumers' Surplus

According to our model, low type purchasers are held at their reservation value across all marketing strategies with or without taxation. On the other hand, high type consumers' surplus is likely to decrease following the intervention. In order for high-type buyers' consumer surplus to either remain unaffected or increase, two unlikely circumstances need to hold true: i) the retailer needs to switch to a one-size-fits-all marketing strategy, and ii) the tax regime needs to be mild enough so that $\psi < \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$. Proposition 2.5.5 summarizes these results.

Proposition 2.5.5 *Suppose that a tax regime (τ_s, τ_v), comes into effect. Then, compared to the pre-tax market screening case I-A:*

1. *L-type consumers' welfare remains unaffected, regardless of the pricing strategy implemented by the seller.*

2. *If the retailer adopts a market-screening scheme (case II-A), H-type consumer's surplus decreases, i.e. $U_H^{ia} = (\theta_H - \theta_L)v(q_L^{ia}) > U_H^{iia} = (\theta_H - \theta_L)v(q_L^{iia})$.*

3. *If the seller targets H-type buyers exclusively (case II-B), then H-type consumers' decreases, i.e. $U_H^{ia} = (\theta_H - \theta_L)v(q_L^{ia}) > U_H^{iib} = 0$.*

4. *If the seller implements a pooling strategy (case II-C), then:*

- *If* $\psi > \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, *H-type consumers' surplus decreases* ($U_H^{ia} > U_H^{iic}$)
- *If* $\psi < \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, *H-type consumers' surplus increases* ($U_H^{ia} < U_H^{iic}$).
- *If* $\psi = \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, *H-type consumers' surplus remains unaffected* ($U_H^{ia} = U_H^{iic}$).

Proof *The i-type consumers' value function is* $U_i = \theta_i v(q) - t_i$. *For L-types, we have:* $U_L^{ia} = U_L^{iia} = U_L^{iib} = U_L^{iic} = 0$. *On the other hand, for H-types:* $U_H^{ia} = (\theta_H - \theta_L)v(q_L^{ia})$, $U_H^{iia} = (\theta_H - \theta_L)v(q_L^{iia})$, $U_H^{iib} = 0$, *and* $U_H^{iic} = (\theta_H - \theta_L)v(q_L^{iic})$.

As long as $\psi > \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, $q_L^{ia} > q_L^{iic} > q_L^{iib}$, *thus* $U_H^{ia} > U_H^{iia} > U_H^{iic} > U_H^{iib}$.

On the contrary, if $\psi < \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]}$, *then* $\theta_L v'(q_L^{iic}) < \theta_L v'(q_L^{ia}) \implies q_L^{iic} > q_L^{iia}$. *This implies* $U_H^{iia} < U_H^{iic}$. ■

2.6 Comparing Taxes and Portion Size Restrictions

Bourquard and Wu (2016) [27] analyze the case of portion size restrictions with the same nonlinear pricing framework we use in this document. As long as the limit in serving sizes does not alter the quantity of the smaller cup, they conclude that a portion cap rule is likely to reduce consumption of SSB among high-type buyers, while at the same time leaving consumer surplus unchanged. This surprising result holds true because the regulation does not eliminate the seller's screening ability and it leaves information rents unaffected. They note that if the portion cap rule is harsh enough, then the retailer could stop offering a menu of two different price-size options and switch to either an "exclusive" scheme serving only H-types or pool the demand by adopting a one-size-fits-all strategy; in this unlikely scenario, the effects on consumer welfare are ambiguous.

According to Bourquard and Wu (2016) [27], when the government imposes a portion size restriction, the retailer solves problem (2.40). The seller seeks to maximize

her expected profit subject to usual incentive-compatibility and participation constrains, plus a restriction on the maximum size per serving (PS). In the economically interesting case, PS is binding, thus $q_H = \hat{q}$.

$$\begin{aligned}
&\underset{(t_L,q_L),(t_H,q_H)}{\text{maximize}} \ (\beta)[t_L - cq_L] + (1-\beta)[t_H - cq_H] \\
&\text{subject to:} \\
&\text{IC} : \theta_H v(q_H) - t_H \geq \theta_H v(q_L) - t_L \\
&\text{IR} : \theta_L v(q_L) - t_L \geq 0 \\
&\text{PS} : q_i \leq \hat{q}, \text{ for } i = \{H,\ L\}
\end{aligned} \tag{2.40}$$

Using our results plus the outcomes derived by Bourquard and Wu, we can compare quantities, prices and value functions derived for each policy environments against our benchmark scenario. Table 2.1 shows such comparison holding the marketing scheme constant.

The major difference between the tax and the portion size restriction is the different effect these policies have on consumer surplus: a tax regime reduces consumer surplus, a portion cap rule does not affect consumer surplus. A tax is akin to an increase in cost of production: it distorts the retailer's cost function and therefore it will induce a quantity reduction in both cups. A portion cap rule is an externally imposed constraint that does not penalize production, it does not either eliminate the seller's ability to endogenously adjust her price-size combinations so as to keep offering quantity discounts and leave surplus on the table for high type buyers. If society decides to reduce soda consumption, we can pursue this goal with either policy tool. Curbing consumption of soda with taxes has the advantage of generating revenue which can be later allocated to fund socially desirable public programs, this comes at the cost of a reduced consumer surplus and an increased production inefficiency. Policy makers can also decrease soda purchases via a cap rule which would not generate governmental revenue bot would leave consumer surplus unaffected. Either regulation would unambiguously reduce retailers' expected profit.

Table 2.1.: Comparing Policy Environments

[Marketing scheme] Policy	q_H^*	q_L^*	t_H^*	t_L^*	U_H^*	U_L^*	$\mathbb{E}[\pi]^*$
[Separating] No regulation	q_H^{ia}	q_L^{ia}	t_H^{ia}	t_L^{ia}	U_H^{ia}	U_L^{ia}	$\mathbb{E}[\pi]^{ia}$
[Separating] Tax Regime	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	-	$\downarrow$
[Separating] Portion Cap	$\downarrow$	-	$\downarrow$	-	-	-	$\downarrow$
[Exclusive] No regulation	q_H^{ib}	0	t_H^{ib}	0	U_H^{ib}	U_L^{ib}	$\mathbb{E}[\pi]^{ib}$
[Exclusive] Tax Regime	$\downarrow$	-	$\downarrow$	-	-	-	$\downarrow$
[Exclusive] Portion Cap	$\downarrow$	-	$\downarrow$	-	-	-	$\downarrow$
[Pooling] No regulation	0	q_L^{ic}	0	t_L^{ic}	U_H^{ic}	U_L^{ic}	$\mathbb{E}[\pi]^{ic}$
[Pooling] Tax Regime	-	$\downarrow$	-	$\downarrow$	$\downarrow$	-	$\downarrow$
[Pooling] Portion Cap	-	-	-	-	-	-	-

2.6.1 Impacts on aggregated welfare

Assume that the government desires to reduce the size of the default large option from q^{ia} to $\hat{q}$. The regulators could either enforce a portion control rule on the large cup or implement a combination of ad valorem and specific taxes that would result in the desired reduction of the large cup. How aggregated surplus compare in the three scenarios? We can quickly realize that aggregated surplus under a cap rule setting $q_H^{ia} > \hat{q}$ would be unambiguously lower. With a tax regime, the sum of producer and consumer surplus is even smaller; however, we need to take into account governmental revenues from taxes. Expected generated revenues fro ad valorem and specific taxes are $t_v \cdot \Big\{\beta\theta_L v(q_L^{iia}) + (1-\beta)[\theta_H v(q_H^{iia}) - (\theta_H - \theta_L)v(q_L^{iia})]\Big\}$ and $t_s \cdot [\beta q_L^{ia} + (1-\beta)q_H^{ia}]$, correspondingly. The levels of aggregated welfare for each regulatory environment are:

$$W_B = \beta[\theta_L v(q_L^{ia}) - cq_L^{ia}] + (1-\beta)[\theta_H v(q_H^{ia}) - cq_H^{ia}]$$
$$W_C = \beta[\theta_L v(q_L^{ia}) - cq_L^{ia}] + (1-\beta)[\theta_H v(\hat{q}) - c\hat{q}]$$
$$W_T = \beta[\theta_L v(q_L^{iia}) - \psi q_L^{iia}] + (1-\beta)[\theta_H v(q_H^{iia}) - \psi q_H^{iia}] + \tau_v\psi(q_L^{iia} + q_H^{iia}) + \tau_s[\beta q_L^{iia} + (1-\beta)q_H^{iia}]$$

Because $q_H^{ia} > \hat{q}$, it is obvious that the baseline aggregated welfare is W_B. Comparing W_C and W_T is a little less straightforward.

Proposition 2.6.1 *Assume that the government regulators want to reduce the default size of the large cup from q_H^{ia} to $\hat{q} < q_H^{ia}$. Suppose that there is a tax regime (τ_s, τ_v) that achieves that reduction such that $q_H^{iia} = \hat{q}$. The aggregated welfare W_C with the cap rule will be larger compared to aggregated surplus W_T if the following inequality holds true:*

$$\beta\theta_L\left[\frac{1}{\theta_L - \left(\frac{1-\beta}{\beta}\right)(\theta_H - \theta_L)} - 1\right](cq_L^{ia} - \psi q_L^{iia}) + (1-\beta)[\hat{q}(\psi - c)] > \tau_v\psi(q_L^{iia} + \hat{q}) + \tau_s[\beta q_L^{iia} + (1-\beta)\hat{q}]$$

Proof *It is a simple algebraic exercise. We wish to show the condition for which* $W_C > W_T$. *We integrate out the expressions in 2.11 and 2.28 to retrieve forms for* $v(q_L^{ia})$ *and* $v(q_H^{iia})$. ■

2.6.2 Parametric Example: Effects on Quantities and Weight Loss

One example may prove helpful for illustration. Imagine two customers (H and L) who eat lunch at a quick service restaurant every day; on average, customer H drinks one 31 ounces cup of soda every day, while L consumes one cup with 7.8 ounces daily. Suppose that the government wants to design a policy such that the maximum cup size offered does not exceed 17 ounces. Policy makers are evaluating whether to implement a portion cap rule or a specific tax. The food retailer price-discriminates by offering differentiated price-size combinations of soda. Assume that the retailer's problem takes the following parametric form:

$$
\begin{aligned}
&\underset{(t_L,q_L),(t_H,q_H)}{\text{maximize}} \ (\beta)[(1-\tau_v)t_L - \tau_s q_L - kq_L^m] + (1-\beta)[(1-\tau_v)t_H - \tau_s q_H - kq_H^m] \\
&\text{subject to:} \\
&\text{IC} : \theta_H q_H^\delta - t_H \geq \theta_H q_L^\delta - t_L \\
&\text{IR} : \theta_L q_L^\delta - t_L \geq 0 \\
&\text{PS} : q_i \leq \hat{q}, \text{ for } i = \{H, L\}
\end{aligned}
\tag{2.41}
$$

Where τ_v represents an ad valorem tax, τ_s a per-unit tax. PS defines the portion size restriction and $\hat{q}$ is the exogenously imposed maximum size under a portion cap rule. In the unregulated case, $(\tau_s, \tau_v) = (0, 0)$, and the restriction PS is inactive. Under taxation, we have either τ_s, τ_v or both strictly positive, and the portion cap rule constraint is inactive. Under portion size restriction, $(\tau_s, \tau_v) = (0, 0)$ and PS is binding. Given a possible set of parameter values, table 2.2 shows the optimal

pricing schedules across policy environments. We assume that the government wants to reduce the size of the large cup from 31 to 17 ounces.

If the government enforces a portion size restriction, consumption by H will drop from 31 to 17 and the small cup size will remain unaffected. A specific tax high enough to reach the same size reduction for the large cup will also affect the size of the small cup, therefore both H and L reduce their consumption.

How are these impacts in quantities reflected in weight loss? Assuming that neither customer substitutes soda for any other product and that they do not compensate for the reduced number of calories post-policy, following [33], and [20], we can calculate their expected weight change resulting from each intervention using the Harris-Benedict formula [34] to estimate steady-state weight losses due to reduction in caloric consumption following a policy intervention.

The Harris-Benedict formula establish a relationship between an individual's weight and her/his basal metabolic rate (BMR), which is the daily number of calories required to maintain the human body at complete rest. This equation takes the following form:

$$\mathrm{BMR} = \alpha + \delta \mathrm{W} \tag{2.42}$$

where α is a function of age, sex and height; while δ depends on the person's sex. According to [35], $\delta = 13.397$ for men and $\delta = 9.247$ for women. To determine an individual's caloric needs I, we need to scale up the BMR equation by a factor γ:

$$\mathrm{I} = \gamma(\mathrm{BMR}) \tag{2.43}$$

The parameter γ equals 1.2 or 1.5 if the individual is sedentary or moderately active, respectively [36]. From equation 2.43 we can estimate a steady-state change in weight ΔW given the difference in caloric intake before and after implementing the regulation ΔI.

Table 2.2.: Optimal Pricing Schedules

	Equilibrium Values						
Policy	q_H	q_L	t_H	t_L	U_H	U_L	$\mathbb{E}[\pi]$
No regulation	31.1	7.8	7784.7	2047.1	70.6	0.0	245.8
Portion cap: $\hat{q} = 17$	17.0	7.8	4355.8	2047.1	70.6	0.0	222.6
Tax: $(\tau_s, \tau_v) = (7.35, 0)$	17.0	4.3	4388.6	1154.0	39.8	0.0	138.3

$\theta_H = 300$; $\theta_L = 290$; $\beta = 0.5$; $\delta = 0.95$; $m = 1$; $k = 240$.

$$\Delta \mathrm{W} = \frac{\Delta \mathrm{I}}{\gamma \cdot \delta} \tag{2.44}$$

Assuming that one ounce of soda contains 11.83 calories, that our hypothetical consumers are moderately active ($\gamma = 1.5$), and that they do not substitute soda for any other product nor compensate for their reduced caloric intake after the policy implementation. In table 2.3 we show steady-state changes in pounds given the modifications in quantities under different policy environments compared against our unregulated benchmark. We assume the government designs its policy so that the largest cup's content diminishes from a hypothetical content of 31 ounces of soda to 17. We display results for a male and a female. We contrast these numbers with the effects on consumer surplus.

We admit that these are rather large changes in weight and are driven by our parametrization among other assumptions. However, table 2.3 highlights the fact that both interventions can reduce consumption of soda if the seller is able to price discriminate and segment the market. Both taxes and cap rules can restrict the size of the largest portion available in the market to a desired quantity target (17 in our example), indirectly setting a limit on the number of calories one consumer can drink in one cup. The table also highlights that the effect of both policies is more severe on high type consumers; these buyers are presumably the individuals these policies are designed for. A portion cap rule has the advantage of diminishing the quantities of soda consumed by buyers who used to purchase large cups while at the same time leaving consumer surplus unaffected.

2.7 Conclusion

In this paper we analyze the economic efficiency and distributional consequences of taxing SSB sales when the retailer engages in strategic nonlinear pricing. We compare the price, size, and welfare outcomes after taxation to the expected effects

Table 2.3.: Steady-State Weight Changes

[Sex] Policy	ΔW_H	ΔU_H	ΔW_L	ΔU_L
[Male] Portion cap	-18.17	-	0	-
[Male] Tax	-18.7	$\downarrow$	-4.55	-
[Female] Portion cap	-11.94	-	0	-
[Female] Tax	-11.94	$\downarrow$	-6.59	-

under a portion size restriction. We also look at how the introduction of tax regimes affects the marketing scheme implemented by the seller. It is important to mention that We do not intend to advocate for or against any type of SSB or food regulation. We do not aim to design a model that mimics all of the details of any specific tax nor any "soda tax" proposed or implemented in the United States or abroad. We offer a general study of the more likely consequences that these interventions would have on sales strategy, cup sizes and welfare distribution.

The key findings in this paper are that after the introduction of a tax regime: i) the size of the package offered to High type buyers is likely to decrease; ii) the Low type consumers' welfare remains unaffected regardless of the marketing strategy adopted by the retailer; iii) The retailer sees her expected profit unambiguously reduced. Not every consumer suffers welfare loss under a taxed environment, only those customers with high willingness to pay for the drink see their informational rents diminished. Since per-unit prices rise, the seller adjusts downwards the size of the small package so she does not loose "low-type" clients and continues to extract surplus from them.

Comparing these effects to the impacts of a portion cap rule, we show that both interventions curb consumption; the effect is larger for high willingness to pay buyers. Unlike a tax regime, a portion size restriction does not affect consumer welfare. Which policy instrument is preferred depends on the criteria that the regulator uses to evaluate the success of the measure. If the only goal is to reduce cup sizes, from a welfare point of view, quantity caps are superior to tax regimes, since they can curb consumption via a reduction in cup sizes leaving consumer surplus unaffected. If the success of the policy is evaluated with basis on its generation of tax revenues, then tax regimes should be preferred, moreover the tax mix should be crafted such that the negative impact on consumption is the lowest because the larger the reduction in consumption, the smaller the tax revenue [30]. If the goal is to reduce consumption, not of SSB, but of added sugars, then more work is needed so as to discern which policy specifically targeting this ingredient reduces its intake in the most economical manner.

Future research projects should include the effects of changes in the other parameters of the model. Examples could include modification in taste heterogeneity (i.e. the difference in willingness to pay between high and low types) via advertising campaigns or others, and changes in the proportion of consumers with high willingness to pay for these foods.

3. NONLINEAR PRICING UNDER REGULATION: COMPARING PORTION CAP RULES AND TAXES IN THE LABORATORY

3.1 Introduction

One of the most pressing public health issues facing the country is obesity. Rates of obesity among adults in the United States hover over 30% [1], and expenses associated with the treatment of its health consequences are estimated to represent between 9.1% and 20.6% of the national health expenditures ([3] [4]). These notable economic and public health impacts have increased public interest in policies aimed at curbing the consumption of foods and ingredients judged to have deleterious impacts on human health. Because Sugar-sweetened beverages (SSB) are the leading sources of added sugars in the American diet, and their frequent intake is linked to weight gain and several chronic deceases, these products are frequent targets of regulations ([37], [8]). Two of these interventions are the object of this paper: per-unit taxes and portion cap rules (policies that limit the maximum default size at which a seller can offer a product). Specifically, we aim to understand the way in which, following an intervention, the sellers modify their pricing schemes and how consumption and consumer surplus change as a results.

In this paper, we report a laboratory experiment designed to formally contrast the economic impacts of per-unit taxes and portion cap rules (caps) in a single-product market whit privately-informed buyers. We rely on nonlinear pricing theory to design an economic experiment where sellers have an incentive to engage in second-degree price discrimination. Holding the consumption-reduction goal for large portions constant in the regulated treatments, we manipulate the policy environment with the intention of i) observing whether sellers modify their segmentation strategies, ii)

quantify differences in consumption, and iii) measure how seller and buyer payoffs change across treatments.

In one of our regulated treatments we induce a reduction in consumption via a per-unit tax. This is because specific taxes are often the first, and sometimes the only, option discussed when authorities in health-conscious localities design 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. There is growing evidence showing that taxes do increase per-unit prices and this translates into reduced consumption of sugary drinks (for example, [20]; [21], and [22])). Most of these studies, however are agnostic about the precise mechanism driving the changes and do not account for endogenous modifications of the sellers' marketing strategies. Because we concentrate on how sellers react to these policies, we complement this literature. Moreover, we also contribute to the body of knowledge by evaluating the potential welfare-reducing impacts of specific taxes that arise from distortions in cost of production.

A less studied alternative to taxes are portion caps. 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 policy instruments to curb the consumption of unhealthy foods ([38], [39], and [40]). In the United States, a prominent example of this type of regulation is the New York City's so-called "soda ban". This regulation was originally proposed to take effect in New York City by 2013. The plan intended to prohibit the sale of SSB 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 [23]. Nonetheless, cap schemes remain an 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. With the hope of informing present and future debates around

food policy making, we compare economic impacts of per-unit taxes and portion cap rules.

In our study, we put a particular emphasis on impacts on consumer surplus because, when proposed, cap rules are assumed to hurt consumers and discussions around are therefore highly contentious. Opponents to caps and similar measures argue that consumers' choice and well-being are infringed by these interventions. Some of them state that caps could disproportionately impact buyers that prefer to purchase larger quantities of SSBs ([41]; [42]). The implication is that diminishing default sizes will result in smaller choice sets and lower consumer welfare. This assumption is already shaping public policy, as exemplified by Mississippi's Bill 2687 (2013). This bill interdicts against future restrictions of food sales within the state based upon the product's nutrition information or upon its bundling with other items. However, because sellers engage in sophisticated pricing schemes, even if a regulation modifies consumption it does not necessarily follow that consumers are worse-off. In hope of informing future food policy design, my objective is to provide formal evidence of the short-term impacts on both surplus and consumption generated by cap rules and taxes when sellers practice second-degree price discrimination. In economics, the theory used to describe the behavior of sellers with incomplete is nonlinear pricing.

Stemming from screening theory, nonlinear pricing helps us to understand why often times the price we pay in the field depends on the quantity we consume, with larger options featuring quantity discounts (lower per-unit price). A nonlinear price is a sorting mechanism used by sellers to mitigate a problem of asymmetric information.[1] According to the theory, the seller designs her pricing scheme relying on self-selection constraints to successfully separate different buyer types. In the canonical single-dimensional adverse selection problem, 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

[1]A complete study of the theory of nonlinear pricing and its applications can be found in [43]

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 ([44]; [32]; [45]). Our premise is that food retailers practice second-degree price discrimination, therefore it is not straightforward to predict how they will modify their menus under different policy environments. We believe that our assumption that food sellers price discriminate is backed by stylized observations. For example, as predicted by the theory, in the field we commonly observe products being offered in small and large options where the large option is price discounted. While simple supply-and-demand models with complete information and homogeneous buyers predict surplus reductions across the board when sellers are regulated, these models are not reliable for describing welfare losses and consumption pattern changes where price discrimination is pervasive.

With our experiment we hope to inform the reader about impacts of caps and taxes on consumer choice set (number of packages offered in different treatments), and changes in surplus. 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 impact by a given intervention, we submit that the policy hurts buyers. If we were to use the textbook microeconomic model of supply and demand presupposing perfect information and passive pricing, we would conclude that reductions in welfare caused by specific taxes and quantity caps can be explained by distortions in both sellers' profit and consumers' information rents. How much of a contribution each source makes to total surplus losses, would be contingent on details regarding elasticity of demand and the severity of the restrictions. In an environment characterized by adverse selection however, what fraction of the reduction in total welfare comes from reductions in consumer or producer surplus depends on the type of regulation. In previous research works were the authors have partici-

pated, we find that this is for two reasons, the seller ought to grant positive surplus to high-type buyers to provide incentives to buyers with high willingness to pay for the product to purchase larger options, and the seller has considerable latitude to structure menus of contracts to induce type revelation and increase surplus extraction, thus she can endogenously modify prices and quantities in order to accommodate an intervention. In short, because the buyer's preference is private information, there is a strong incentive for the seller to engage in market segmentation, and alternative policy environments will distort these incentives in different ways. Maximum quantity caps do not remove the problem of asymmetric information and thus the incentive to separate buyer types remains. The seller endogenously adjusts her screening contracts in order to continue to grant positive payoffs to buyers with higher valuations fr the product. Theory predicts that reductions in welfare attributable to quantity caps are entirely explained by reductions in profit [46]. This is not the case with per-unit taxes [47]. A per-unit fee (a specific tax) is akin to an increase in marginal cost of production. Reduction in total surplus arises as a result of reduced output for all buyer types. Both consumer and producer surplus are negatively affected and input is distorted away from the unregulated optimal. In this paper, we provide experimental evidence supporting these results.

The second policy-induced change we investigate corresponds to possible changes in the number of packages sellers offer in different policy scenarios. We select parameters in our experiment so that market segmentation is optimal for the seller. Thus, in theory, the seller should offer two incentive compatible packages to serve two privately-informed buyer types. Our data suggests that subjects taking the role of sellers are as likely to offer two-item menus with cap rule, but less likely to offer two options under a tax regime. This finding is important because the claim of a negative impact on consumer choice is often made to disregard portion cap rules but virtually never raised when considering excise taxes.

The rest of the document is organized as follows. The next section succinctly describes related scientific literature. In section three we introduce the model we used

to design our experiment, 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 here we also include the finding regarding how often subjects in the role of sellers attempt market segmentation by offering two packages in the different experimental conditions. In section six, we list the major results involving impacts on consumed quantities and payoffs.

3.2 Related literature

Even though in most jurisdictions where they exist soda taxes have been active for a relatively short period of time, there is a large and growing literature evaluating their efficacy at reducing consumption. Some studies (see, for example [18]; [20]; [21], and [22]) find support for the hypothesis that such taxes do reduce consumption of the targeted products. The literature looking at the impact of these taxes on population weight shows mixed results. Some studies suggest that there are no significant impacts and these may not depend on the size of the tax ([31]; [48], and [49]); while others suggest that the effects may be more susceptible among "high risk" populations [50]. Thus, the literature suggests that taxes do reduce consumption albeit the evidence on the impacts on health benefits is mixed.

Regarding studies analyzing the effects of portion cap rules, [28] (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 that would modify her pricing strategies following the intervention.

[29] 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, John et al 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 [29] in that our subjects take on the role of sellers, as opposed to buyers. We vary the policy condition (baseline, cap, and tax) 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. In order to design our laboratory experiment, we take theoretical predictions from [46] and [47]. Both of these papers analytically study the impacts of regulating a monopolist that designs nonlinear price schedules. Bourquard and Wu are interested in learning the impacts of size-caps, while Balagtas et al look at the effects of per-unit taxes and compare them to the expected impacts of cap rules. Bourquard and Wu analyze portion size restrictions with the same nonlinear pricing framework we use in this document. Their model includes a price-discriminating seller facing demand form a buyer with two potential willingness to pay for soda. They conclude that portion caps do reduce cup sizes and, as long as the allowed maximum size is larger than or equal to the smaller container offered under no regulation, consumer surplus remains unaffected. This is because adverse selection provides a strong incentive for the seller to adjust post-regulation prices down. The key difference between our work and theirs is that we also examine the impact of SSB taxes and then compare the economic effects of the two policies.

To the best of our knowledge ours is the first empirical study comparing per-unit taxes and portion cap rules. 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. [51] 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. [52] 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 generation and distribution.

3.3 Theory

In this section we describe the model from which we derive our hypotheses. We characterize the seller's optimal pricing strategies in three policy environments: unregulated baseline, portion cap rule, and per-unit tax. Although, for the parametrization we choose for the experiment, the best pricing strategy consists of two incentive-compatible packages, human subjects could engage in sub-optimal single-package schemes, thus we also characterize them.

Consider a standard adverse selection model in spirit of [45] and [44]. One seller faces demand from a privately-informed buyer. There are two types of buyers characterized by their preference for the product. With probability $(1-\beta)$, the buyer is a High-type (H) buyer that 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, the i-type buyer earns consumer

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. 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.

The seller chooses prices and quantities to maximize her expected profit subject to the relevant participation and incentive-compatibility constraints. There is a cost of production c incurred by selling one unit of the product.

3.3.1 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). Thus, her maximization problem is:

$$\max_{(p_H, q_H, p_L, q_L)} \quad \mathbb{E}[\pi] = (1-\beta)\Big[p_H - cq_H\Big] + \beta\Big[p_L - cq_L\Big]$$

subject to

PC: $\theta_L u(q_L) - p_L \geq 0$

IC: $\theta_H u(q_H) - p_H \geq \theta_H u(q_L) - p_L$

The seller's objective function weights the profit contribution of serving both buyer types by the probability of the customer she faces being of either type. As we will show later, taxes and caps modify the optimization program in different ways, taxes distort profit contributions, while caps reduce the sellers choice space. Importantly, the price discriminating seller considers two constraints: a participation constraint, and an

incentive-compatibility constraint. Because these restrictions play an important role on the outcomes of the regulations, we briefly discuss them.

The PC restriction ensures that the that all buyer types find it in their interest to participate by purchasing one of the packages offered by the seller. In other words, both buyer types find that their expected surplus is at least zero when they participate. Only one buyer type's PC is included because if the seller desires 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 pricing scheme to be individually rational. Because the reservation value for the L-type is zero, his expected utility when participating is ensured to be at least zero: the utility he would obtain if he did not buy any package and did not pay anything.

The IC restriction plays an essential role in separating the buyer types. In this application, we say a menu of two packages to be 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 taste parameter θ_i, satisfying the monotonicity condition $q_H > q_L$. Because at the optimal the constraints will bind with equality, we can substitute them into the expected profit function and re-express the seller's problem as in equation 3.1. Notice that the objective function is not linear with respect to quantity because q enters $u(\cdot)$.

$$\max_{q_L, q_H} \quad \mathbb{E}[\pi] = \theta_L u(q_L) - cq_L + \left(\frac{1-\beta}{\beta}\right)\Big[\theta_H u(q_H) - (\theta_H - \theta_L)u(q_L) - cq_H\Big] \quad (3.1)$$

Depending on how prevalent L-types are in the population (which is captured by the parameter β) and how large the taste dispersion $(\theta_H - \theta_L)$ is, there are occasions where pooling or exclusive strategies dominate separating mechanisms. Because our premise is that nonlinear pricing is pervasive in the food industry, in our experimental design we choose parameters that ensure that separation of types is optimal. In the

subsection below we characterize the optimal separating schemes for all three policy environments we consider in this paper. For completeness and because subjects may decide to offer single-package contracts we include the characterization for the best pooling and exclusive contracts in the appendix.

Baseline

When the seller adopts a separating pricing schedule to serve both buyer types, the quantities (the endogenous variables in the maximization problem 3.1) satisfy the first order conditions in 3.2.[2]

$$\text{Baseline-separating-quantities} \begin{cases} \theta_H u'(q_H^{*1}) = c \\ \theta_L u'(q_L^{*1}) = \frac{c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]} \end{cases} \tag{3.2}$$

With these quantities (3.2), 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 and grants positive surplus to the H-type and no surplus to the L-type consumer.

The resulting 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 receive a quantity smaller than his first-best consumption.

[2]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.

3.3.2 Cap rule

When a cap rule limits the maximum allowed quantity to an arbitrary number of units $\hat{q}$, such that $q_L^{*1} \leq \hat{q} \leq q_H^{*1}$, the seller still chooses quantities to maximize expected profit expressed in 3.1, subject to the following portion cap rule (PCR):

$$\text{(PCR): } q_i \leq \hat{q} \quad \text{for} \quad i = L,\, H \tag{3.3}$$

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. $q_L^{*1} \leq \hat{q}$. This is consistent with the proposed portion cap rule for sodas in NYC in 2012. The quantities that characterize the best separating contract satisfy the following first order conditions:

$$\text{Cap-separating-quantities} \begin{cases} \theta_H u'(q_H^{**1}) \geq c, \text{ where } q_H^{**1} = \hat{q} \\ \theta_L u'(q_L^{**1}) = \dfrac{c}{\left[1 - \left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H - \theta_L}{\theta_L}\right)\right]} \end{cases} \tag{3.4}$$

With a menu of two packages, the Low-type buyer gains no information rents. The High-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 and the L-type's expected utility neither of which are negatively impacted by a regulation where $q_L^{*1} \leq \hat{q} \leq q_H^{*1}$. More intuitively, as the regulation moves the size of the large package down, the seller adjusts the price down accordingly in an effort to keep separating the types.

3.3.3 Per-unit tax

The second policy instrument we study in this paper are per-unit taxes. The specific tax t_s modifies the seller's optimization program in the following way:

$$\begin{aligned} &\max_{(p_H,q_H,p_L,q_L)} \quad \mathbb{E}[\pi] = (1-\beta)\Big[p_H - t_s q_H - cq_H\Big] + \beta\Big[p_L - t_s q_L - cq_L\Big] \\ &\text{subject to} \\ &\theta_L u(q_L) - p_L = 0 \\ &\theta_H u(q_H) - p_H \geq \theta_H u(q_L) - p_L \end{aligned} \tag{3.5}$$

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

$$\text{Cap-separating-quantities} \begin{cases} \theta_H u'(q_H^{***1}) = t_s c \\ \theta_L u'(q_L^{***1}) = \frac{t_s c}{\left[1-\left(\frac{1-\beta}{\beta}\right)\left(\frac{\theta_H-\theta_L}{\theta_L}\right)\right]} \end{cases} \tag{3.6}$$

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.

3.4 Experimental design and hypotheses

3.4.1 Selection of parameters

In this section we present the design of our experiment, list the hypotheses we will test with the experimental data. With this experiment, we aim to empirically compare the impacts of portion cap rules and per-unit taxes on consumers' information rents, sellers' profit, and total surplus. We use the nonlinear pricing model described in the previous section to inform our design. Table 3.1 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, payoff-maximizing subjects would 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.

In our experiment, we have three treatments across which we vary the policy environment. 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 3.2 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 3.3 presents figures describing the contracts that result in the maximum expected profit for a given segmentation strategy.

The purported objective of portion cap rules, such as the NYC sugary drinks portion cap rule, 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 way below the average 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.

Table 3.1.: 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 3.2.: 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 3.3.: 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.

3.4.2 Hypotheses

Main 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 and one large package 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 serving sizes. 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 buyer. 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. For each of the surpluses, we rank the treatments according the level of the corresponding surplus we expect to measure according to the theory and for the chosen parametrization.

***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. Moreover, the L-type buyers are kept at their reservation value, that is *Baseline* = *Cap* = *Tax* = 0.

***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, although it could potentially be welfare improving if lump-sum transfers are made to consumers.

Outcomes with sub-optimal single-package offerings

For completeness, we list what the impacts would be for sellers who adopt single-package strategies, either pooling or exclusive. The main objective of this subsection is to summarize theoretical outcomes shown in the appendix. These show that if the seller implements a single-package strategy before the enactment of a regulation, then the portion cap rule would not negatively impact the surplus of either type, and the tax would reduce the H-type's surplus but not the L-type's payoffs.

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 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 do not change under any policy scenario.
- Seller's earnings are diminished by both interventions.

The effects on served 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.
- H-type's earnings are not impacted by either intervention.
- The L-type's surplus do not change under any policy scenario.
- 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.

3.4.3 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 [53], where most volunteers are students at Purdue Universty. The experimental

interface was implemented using oTree [54]. 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.

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 as 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 a balance of 500 points in the *Tax* treatment, and had no starting balance in the other treatments. Average earnings in 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 processes. 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, 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 and adopt a utility-maximizing decision without worrying about the possible interpretations that a human buyer could give to her decisions. A second reason behind our decision of automating the buyer's role is to ensure that our results are not driven by inequity aversion, the regularity observed in several economic experiments wherein participants in laboratory economies give up some of their own payoff to avoid inequitable outcomes [55]. Deviations attributable to inequity aversion have been mostly studied in one-shot games such as the ultimatum game[3], and their role in experiments testing principal-agent theoretical outcomes is less understood. In an experimental test of the canonical adverse-selection problem, [58] 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 Hoppe and Schmitz's, adding worries regarding beliefs about how rational buyers are would only difficult the analysis of the effects of interest.

3.5 Results: Data overview

Throughout this and the next sections, we present two categories of outcomes. 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 3.4.2 are classified as results. Before we present our main results, we first explore

[3]For examples, see [56] and [57].

the general patterns encountered in the data.[4] We are primarily interested in finding whether our subjects behaved 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.

3.5.1 Do sellers attempt to separate buyer types?

Sellers do offer two-option menus more often than single-package offers. Table 3.4 presents descriptive figures from within treatment outcomes. [5] 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.

[4]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.

[5]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 3.4.: 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 3.5.: 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.

Even though the majority of submitted offers contain two alternatives. There is a reduction in the proportion of menu offers in the two regulated groups compared to the baseline. This is because the regulation reduces the difference in sellers' earning between the best separating schemes and the best single-package strategy. 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 10.4% and 15.8%. 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 two-item 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 3.5 exhibits descriptive figures from within treatments regarding the buyer's decisions. The table shows decisions, average purchased quantities, and paid prices by buyer type. At any given trading period, the seller faces demand from a single buyer. Using the seller's submission we infer what package would each type of buyer purchase. We use these inferred consumption patterns in all the analyses of buyers' decisions in this document. 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 3.4 and 3.5, 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.

For completeness, we look at how often subjects satisfy relevant incentive constraints. In table 3.6 we look at how often subjects' offer satisfied relevant incentive constraint. The upper panel refers to menu offers. Recall that 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 3.6 refers to single-package offers. Most offers satisfy the H-type participation restriction in all treatments. The majority of offers satisfy the L-type in *Baseline* and *Cap*, however the majority of offers do not satisfy the Low-type participation constraint. 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 it as either a pooling or an exclusive offer with 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 participation restriction of the High-type buyer, then we consider it to be exclusive.

The fact that 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, imply that subjects that adopted single-package strategies understood the instruc-

Table 3.6.: Satisfaction of incentive constraints

	Baseline	Cap	Tax
Menu offers:			
Incentive Feasible	192/277 (69.3)	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.

tions. Participants proposing a single package implemented their pricing schemes (either exclusive or pooling) with success.

3.5.2 Do the interventions result in equivalent quantity reductions?

Recall that in theory, with the parameter constellation we choose, both interventions ought to result in a reduction of the optimal quantity of largest package from 32 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. 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 where we address the main hypotheses of the paper and present our main empirical results, 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 3.7. According to our econometric 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 3.7.: Estimates of the Impacts of the Regulations on 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.

In general, the main result to be presented in 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* where significantly smaller, the cap does not impact consumers, while the per-unit tax does. We present evidence in the sections below.

3.6 Major results: Comparing the impacts of caps and taxes

In the previous section we showed data patterns that align with some of the major predictions of nonlinear pricing theory. In particular, most of the time our subjects attempted separating pricing schemes with relative success. This is comforting since it inspires confidence in the theory, experimental implementation, and subjects' comprehension of the instructions. We now turn to our main research goals, namely 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, and sellers' expected profit. For completeness, we also look at the interventions' effects on consumer surplus, defined as the sum of expected profit and consumer surplus plus tax revenue where applicable. The first subsection address 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 without looking at 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.

3.6.1 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 3.8, the reduction in the probability of offering menus is only statistically significant in the *Tax* group.

Table 3.8.: 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.

***Result** 1.* **Separation of types:** *Although most subjects offered two-package menus in all treatments, in alignment with hypothesis 1, the subjects were significantly less likely to offer menus with two alternatives 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 show table 3.7 in the previous section when discussing whether the reduction in large serving sizes was equivalent across the active treatments. Table 3.7 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 look at plausible 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 rule. 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 predicted 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 under both polices, the reduction in *Tax* is more pronounced.

Table 3.9 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 hypotheses 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 hypotheses 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 hypotheses 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 hypotheses 5, when sellers offer two-package menus, there is no statistically significant decline in expected per-period profit.*

Table 3.9.: 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.

Results 3 and4 concern changes in expected buyer surplus and align with the theoretical predictions. A natural way of explaining these effects in surplus given the changes in quantities reported in 3.7 is to look at the changes in the per-package prices Sellers decided on during the different treatments. In table 3.10, we report econometric estimates of the impacts in prices offered by sellers.

Consumers remain unaffected by the portion cap rule because our sellers adjust prices down to keep consumer surplus across the regulatory environments we study. The intuition is simple, because the incentive to separate buyer types exists in all policy environments, the seller must ensure that the H-type consumer does not prefer the small alternative over the large portion and she does so by manipulating prices.

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

Table 3.10.: Estimates of the Impacts of the Regulations on 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.

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 across 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 3.11, we present econometric estimations 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. We conclude that in the under a portion cap, sellers adjust

both quantity and prices in such manner that the sum of profit contributions remains unchanged compared to *Baseline*.

Table 3.11.: Estimates of the 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.

At this moment we end the discussion of our main results: 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 a single package.

3.6.2 Impacts when sellers adopt single-package strategies

Table 3.12 presents our estimates regarding offers containing a single package. The first column shows the estimated coefficients for pooling offers (when the single package would have been consumed by either buyer type), while the second column

presents results when the sellers offered an exclusive offer (an offer that would have been rejected by the L-type buyer).

Table 3.12.: Estimates of the Impacts of the Regulations on Quantities - Offers with one package

	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.

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

Looking at pooling strategies, the reduction is not equivalent in the *Cap* and *Tax* treatments (Wald test p-value = 0.03). 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% but not at the 5% level. According to the model and from results listed in the appendix, assuming that sellers do not change

their strategy following the intervention, the 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 3.13, 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 model's predictions shown in the appendix, the only regulation affecting consumer surplus when sellers pool the demand is the specific tax.

Table 3.13.: Estimates of the Impacts of the Regulations on Per-period Payoffs - Pooling offers.

	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.

Table 3.14.: Estimates of the Impacts of the Regulations on Per-period Payoffs - Exclusive offers.

	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 table 3.14 we show how the interventions impacted the variables of interest. As anticipated, expected profit is lower in both active treatments, however we cannot reject the hypothesis of the estimated impact in *Cap* and *Tax* to be equal. Similarly, total surplus is reduced in both regulated treatments, however the reduction is not statistically different. Buyers' consumer surplus is not impacted by the regulations. This is because L-types do not participate earning their reservation value of zero, while H-types are held close to their reservation value. These outcomes align with the theoretical model's outcome presented in the appendix.

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.*

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-package offers.

3.6.3 Surplus impacts with the aggregated data

A natural question the reader might have is whether we observe impacts in consumer surplus when looking at the aggregated data (without parsing the data depending on the subjects' strategy) that are different from the patterns identified when we look at the results contingent on the sellers' scheme. In table 3.15, 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.

Table 3.15.: Estimates of the 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.

Thus, when we aggregate the data and ignore the segmentation scheme adopted by the seller, we find the same consumer surplus patterns we found when looking at the outcomes contingent on the pricing scheme. L-type buyers are not impacted by the regulations, while H-type's are negatively affected only in the *Tax* treatment.

3.7 Conclusion

In this document, we report a laboratory experiment on single-product nonlinear pricing with contracting restrictions. We compare two interventions that have been proposed as alternatives to restrict the consumption of foods judged to have 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 experiment consists of three treatments. A *Baseline* group where sellers are free to set prices and quantities without restrictions; a treatment *Cap* that limits the maximum quantity to about half the theoretically optimal for large packages, but above the size of the optimal quantity for small packages; and a treatment *Tax* where we impose a per-unit fee that would theoretically reduce the quantity of the large packages to levels comparable to the cap rule.

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. There are three segmentation schemes sellers can implement: i) separating schemes where they submit two-package menus; ii) pooling strategies where they offer a single package that would be purchased by either type of buyer, and iii) exclusive offers where the seller submits a single package which that would not be bought by the Low-type buyers.

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.

To the degree that separating pricing schemes are pervasive in the food retail industry, we believe that our study shows that moderate portion cap rules should be consider as a food policy regulation alternative with neutral impact on consumers' surplus. Although the alternative of limiting the default size of large soda cups has been dismissed in some jurisdictions, it still remains a viable legal option to regulate consumption of sugary drinks somewhere else.

4. MULTI-PRODUCT NONLINEAR PRICING WITH PORTION CAP RULES: EXPERIMENTAL EVIDENCE

4.1 Introduction

In this paper, I present an economic analysis of portion cap rules (caps). These are policies restricting the default quantities at which food products can be offered. In light of studies linking larger portion sizes to increased consumption, foods containing ingredients judged to have deleterious impacts on human health are common targets of proposed caps ([38], [39], and [40]). One example of such policies is the so-called "New York City soda ban". The advanced plan intended to prohibit food vendors regulated by the city of New York from selling sugar-sweetened beverages (SSBs) in containers exceeding 16 ounces [59].[1] Ultimately, this proposal was struck down in court [23]. Nevertheless, discussions about possible implementations of similar policies in the food retail industry are ongoing and contentious.

Opponents to caps and similar measures argue that consumers' freedom, choice, and well-being are infringed by these interventions. Some of them state that caps could disproportionately impact buyers that prefer to purchase larger quantities of SSBs ([41]; [42]). The implication is that diminishing default sizes will result in lower consumer welfare. This assumption is already shaping public policy, as exemplified by Mississippi's Bill 2687 (2013). This bill interdicts against future restrictions of food sales within the state based upon the product's nutrition information or upon its bundling with other items. However, because sellers engage in sophisticated pricing schemes, even if a regulation modifies consumption it does not necessarily follow that consumers are worse-off. In hope of informing future food policy design, my objective

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

is to provide formal evidence of the short-term impacts on surplus generated by cap rules when sellers offer bundles of two products.

In this paper, I study a seller who offers packages containing quantities of two products serving heterogeneous buyers with private preferences over these goods. Throughout the paper, I refer to these goods as product A and product B. Suppose that product A is subject to a portion cap rule. The questions I aim to answer are: i) whether the intervention reduces consumption of the targeted item A, ii) what is the impact on the purchased sizes of the *unregulated* component B, and iii) what is the effect on consumer surplus, this is the gross utility from consumption net of the price paid also known as information rents. To provide answers to these questions, I concentrate on studying seller's pricing behavior because changes in surplus distribution and consumption patterns are ultimately contingent on how the pricing scheme is modified following a regulation. My analysis of the seller's response to the intervention has two parts: first, I generate predictions from a bi-dimensional nonlinear pricing model; second, I use data from a laboratory experiment to test the model's hypotheses.

I refer to the quantity of a given product (A or B) as a "portion" and to specific combinations of quantity of A and quantity of B offered by the seller as "packages" or "combos". In the theoretical model, one seller (she) designs a menu of package-price combinations. One buyer (he) with privately known preferences for A and B chooses his consumption from the menu of choices. There are four types of buyers characterized by their preferences over the products. Each product can be either highly (H) or lowly (L) preferred by the agents. The ij-type buyer has preference i for good A, and j for component B. The model predicts that without regulation, the seller offers "small-small", "medium-large", "large-medium", and "large-large" A-B combos. Consumer surplus is the largest for the HH-type buyer, and lowest for the LL-type. When the medium HL and LH types' surpluses are positive, they fall between these extremes. If a portion cap rule is enforced such that the seller is required to offer portions of A strictly lower than the "medium" unregulated size,

the model predicts: i) all purchased sizes of A are reduced, including that of the "small" option; ii) consumption of the unregulated component B increases for the LL-type, and decreases for the HL-type, and iii) information rents for the HH-type are smaller, but they are larger for the LH-type. I conduct a laboratory experiment to test these predictions. In line with the hypotheses, I find that all consumers lower their consumption of the regulated component, and the LH-type buyer enjoys a larger surplus. On the other hand, contrary to the predictions I find no significant impacts neither on the consumption of product B, nor in the HH-type buyer's earnings.

This research is important and timely because as obesity rates in the United States hover over 30% [1], I expect campaigns against consumption of foods and ingredients associated with obesity and its health consequences to intensify. In effect, not only public health officials have proposed cap restrictions as a food policy tool, some voices within the private sector seem to recognize their potential as a cost-effective method to aid the abatement of obesity [25]. At the same time and in parallel to an increase in the demand for consumption-curbing regulations, I also expect more campaigns opposing cap rules on the grounds of alleged potential reductions in consumer well-being. To help inform the discussion and design of effective food policies, a strong body of academic knowledge is essential. The academic community and policy officials are relatively well informed about the impacts of some policy tools used to regulate food consumption such as excise taxes. There is however, a relatively smaller literature on the economic consequences of portion cap rules. In this research I address this relative paucity by looking at the specific case of multi-product markets.

The multidimensional nature of the pricing problem I present in this paper is an important feature. Most food retailers are multi-product sellers that leverage the wide spectrum of available items they sell to implement sophisticated price-discriminating strategies. Importantly, they can engage in commodity bundling. Commodity bundling is the screening device wherein the price of a bundle containing various items in combination is lower than the sum of the prices for the stand-alone products. Alternatively, if two goods are always sold together in packages containing

both components (the scheme known as pure bundling), they are said to be bundled if the variance in price across different packages is not entirely explained by differences in marginal cost of production[2]. In this document, the seller implements a version of pure bundling. A and B are always consumed together, except in instances where she explicitly sets the quantity of one of the products to zero. This may appear to the reader as a restrictive assumption potentially dampening the predictive power of the model, and its parallelism with what it is observed in the field. I argue this assumption is not as restrictive as it appears because it simplifies experimental implementation and it can reflect pricing schemes of products we typically do not think of as bundles. For example, consider a soda or soft drinks manufacturer deciding sugar-water (A-B) combinations. [3] In this case, the "package" is a bottle of soda with a particular sugar-water ratio. The model predicts that, without regulation, the seller decides to produce bottles of soda in different presentations: bottles with a one to one sugar-water formula in small and large options to cater to LL and HH-types (the small-small and large-large A-B combos); a "concentrated" formula with a high sugar-water ratio designed for the HL-type's sweet taste (the large-medium A-B combo), and a "light" water-diluted presentation with low sugar-water ratio serving the health-conscious LH-type (the medium-large A-B combo). In this case, the portion cap takes the form of a restriction in the maximum quantity of sugar allowed in a bottle of soda.

In the model, the components offered by the seller are neither complements nor substitutes. This is to emphasize the tension between the multidimensional nature of the incentive-design problem. In doing so, I can argue that all the characteristics of the allocation outcomes before and after the regulations are solely due to the seller's desire to segment demand; nothing else can influence the outcomes because potentially confounding factors (such as complementarity) are absent. In other words, I show

[2]For a formal discussion of pricing strategies in markets with imperfectly informed sellers, I refer the reader to [43].

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

that a cap rule changes allocation and consumer surplus even when the products are independent. Moreover, bundling of non-complements is not an uncommon practice even in the food retail sector; for example, several supermarkets engage in pricing strategies that tie gasoline price discounts with consumption of groceries.[4]

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

The rest of the document is organized as follows: in the next section, I succinctly describe the related academic literature; in section 3 I formally introduce the theoretical model and derive the theoretical hypotheses; in the fourth part, I present

[4]The reader can consult [60] for a study regarding this specific instance.

the experimental design; in section 5, I present the laboratory data and discuss the experimental results; the last section concludes.

4.2 Related literature

This paper contributes to the body of knowledge in food policy design, applied industrial organization, and multidimensional nonlinear pricing.

Because my empirical project relies on the theoretical multiproduct nonlinear pricing literature, I present a brief review of the field. Stemming from screening theory, multidimensional nonlinear pricing is notorious for being a source of research queries easy to state but difficult to solve analytically. The early literature on bundling relied on stylized instances and the single-crossing assumption. [61] uses a series of examples to show that mixed bundling is a preferred strategy for the seller when the valuation for the item is negatively correlated. [62] shows that a monopolist can extract almost all possible surplus by price discrimination via a two-part tariff. [63] generalized the result of bundling as a preferred strategy by showing that the first order conditions necessary for component pricing to strictly dominate any alternative fail, therefore some form of bundling always does better when the distribution of types is continuous. A growing literature is exploring how robust the early outcomes are to simplifying assumptions. Even "null" results prove a significant contribution to the field; for example, without assuming single crossing, [64] shows that when a seller faces a buyer with several dimensions of private information, and the seller knows the marginal distribution of each product of the buyer's type but ignores the joint distribution, then it is in the seller's best interest to engage in component pricing (as opposed to bundling). [65] offer a review of the bundling literature and discuss how theoretical results are highly sensitive to assumptions on factors such as marginal cost of production, correlation of types, interactions between the components (complementarity, for example) and competition. Because of the complexity implied, [66] point out that applied researchers hinder from studying problems where multidimen-

sional screening provides the theoretical framework, despite of the several potential applications of the theory. This paper aims to contribute to the applied literature in multidimensional screening.

The topic of regulating price-discriminating sellers has been intensely studied in the field of industrial organization, although the specific intervention of maximum quantity caps in multi-dimensional screening models seems to be a contribution of mine. The existing literature tends to rely on theoretical predictions. Moreover, both analytical and empirical works either concentrate on the single-product case or rely on a multidimensional version of the single-crossing condition to facilitate the analysis. As a result of adverse selection, price-discriminating firms distort quantity downward along the type space. In a theoretical paper, [51] explore the effect of three regulatory measures intending to fix this distortion: minimum quality standards, maximum price regulation, and rate of return regulation. Besanko and co-authors derive conditions under which the rate of return regulation lowers quantity for the high-types; they also demonstrate that maximum price interventions lower quantity for the high-types, while minimum quality standards do not modify the quantity consumed by the buyers with high valuation for the goods. [52] analytically studies the effect of imposing a price-cap on the lower level of quantity offered by a multi-product monopolist. Corts relies on a multidimensional version of the Spence-Mirrlees single crossing condition to analyze the multidimensional problem with a one-dimensional screening model. He finds mixed results regarding prices paid by different buyer types. In a numerical example where the multi-item single-crossing assumption is relaxed, Corts show how socially suboptimal unbundling may arise as consequence of the intervention. [67] consider two forms of regulations: a cap on the seller's average revenue, and a constraint that forces the seller to keep offering the option to buy a component at the uniform price. Armstrong and co-authors show that the average revenue constraint is preferred by the seller.

Moving to experimental research, [68] and [69] are largely concerned with evaluating outcomes from the leverage theory of product bundling, where a multi-product

firm competes in two markets, A and B. The firm is a monopolist in market A and faces fringe competitors in market B. The main concern of scholars studying tying is that the multi-product firm may leverage market power from market A to incur in extraordinary rents in market B. In this paper, I am concerned with learning about pricing strategies of a regulated multi-product monopolist with presence in a single market, thus my research speaks to a different, although closely related, literature. An experimental paper testing nonlinear pricing is [58] where the authors test the canonical adverse selection model wherein a seller makes a contract to try to separate a privately informed buyer who has preferences over a low and a high quality item.

More directly related to the topic of regulating food vendors, [28] conduct an interesting behavioral study. They aim to determine how a limit on sugary drink portions might affect consumption patterns. The authors put to the consideration of human subjects a hypothetical menu of options, and the subjects were asked to choose how much food they would like to consume. The authors contrast consumption choices made under two types of menus: a baseline menu where the vendor offers soda cups without any regulation, and an active group where the seller replaces large cups (say of 32oz) with smaller containers (say of 16oz). Their main finding is that buyers decide to purchase more soda with the regulated menu featuring the portion cap rule. This study is useful since it provides an insight regarding potential framing effects that could alter subjects' purchase decisions. My paper complements the work conducted by Wilson and co-authors in two dimensions. First, my analysis concentrates on the seller's side of the story. A complete explanation of the consequences of an intervention ought to include analyses of reactions from buyers and sellers. Secondly, my experiment ties monetary rewards to subjects' performance. That is, I reward subjects for taking actions that would make the hypothetical market player they are playing for better off.

My research is an extension of [46], and [47]. These papers analytically and experimentally study the impacts of portion cap rules with single-product sellers trading with privately-informed heterogeneous buyers. They report that a portion

cap reduces consumption without affecting consumer surplus. The reason is that as the cap limits quantity, the seller adjusts prices accordingly so as to leave consumer rents unaffected. They also compare cap rules versus taxes and find that taxes do reduce consumer surplus.

4.3 Theory

In this section, I introduce a model largely based on the multidimensional screening model of [66], though I simplify it to facilitate experimental implementation. To illustrate the main features of the theoretical model and how the regulation would be incorporated to the model, I present the characterization of the optimal price schedule before and after the cap. Following succinct discussions of the optimal solutions, I introduce a parametrization of the model.

4.3.1 Model

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

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

The subindex in R, q^A, q^B, and p indicates the type of consumer. I assume away interactions between the components. Thus, the two goods are neither substitutes

nor complements. In this manner, I emphasize the relationship between the multi-dimensional incentive constraints and the seller's pricing decisions. This assumption has advantages regarding experimental design that facilitate the interpretation of results. This simplification provides this study with a neutral background where changes across treatments can be confidently attributed to the impact of quantity restrictions on pricing behavior without the confounding effects that complementarity would bring about.

I assume $u(\cdot)$ to be continuous, also $u(0) = 0$, $u'(q) > 0$ and $u''(q) < 0$. Buyer's preferences satisfy the Spence-Mirrlees single-crossing condition. Both, the seller and the buyers have reservation values of zero. I assume both goods to have the same differentiable, increasing and convex cost function $c(\cdot)$ without interactions. Also, $\theta_H u'(q) > c'(q)$ and $\lim_{q\to\infty}\theta_H u'(q) < c'(q)$, so that trade is possible at least with the HH-type, and total quantity supplied is finite. $\sum_{ij}\beta_{ij} = 1$, so β_{ij} represents the probability that a given buyer is of an ij-type. Lastly, let $\beta_{HL} = \beta_{LH} = \beta$ so that instances HL and LH are equally likely. The seller's expected profit is:

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

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

$$\mathbb{E}[\pi] = \underbrace{\sum_{ij}\beta_{ij}[\theta_i u(q_{ij}^A) + \theta_j u(q_{ij}^B) - c(q_{ij}^A) - c(q_{ij}^B)]}_{\text{Expected total surplus}} - \underbrace{\sum_{ij}\beta_{ij}[\theta_i u(q_{ij}^A) + \theta_j u(q_{ij}^B) - p_{ij}]}_{\text{Expected consumer surpluses}} \tag{4.1}$$

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

$$\text{PC: } R_{ij} \geq 0 \;\forall\; ij \tag{4.2}$$

The set of incentive-compatibility constraints are self-selection conditions designed to provide incentives for higher types to choose packages with larger quantities. Separating higher types is beneficial to the seller because larger packages are associated with larger profit contributions. These incentive conditions ensure that the ij-type buyer does not find it advantageous to purchase a package originally intended to serve a kl-type buyer (where $i \neq k$, and $j \neq l$). This implies that, at the optimum, quantities and prices are such that the ij-type buyer is weakly better-off by choosing contract $\{q_{ij}^A, q_{ij}^B, p_{ij}\}$ over contract $\{q_{kl}^A, q_{kl}^B, p_{kl}\}$. More precisely, the seller designs these two contracts such that the ij-type receives a temptation payoff known as information rents in the mechanism design and screening theory literature. These rents are exactly equal to the extraordinary rent the ij-type would have gained had he chosen the contract intended for the kl-type from a menu with linear prices. Formally, the IC constraints take the following general form:

$$\text{IC: } R_{ij} \geq R_{kl} + \underbrace{u(q_{kl}^A)(\theta_i - \theta_k) + u(q_{kl}^B)(\theta_j - \theta_l)}_{\text{Rent gained by the } ij\text{-type from posing as a } kl\text{-type}} \quad \forall\; ij \text{ and } kl; i \neq k \text{ and } j \neq l \tag{4.3}$$

The complete optimization program includes 8 PC and 12 IC restrictions. The seller's goal is to design a menu of contracts $\{q_{ij}^A, q_{ij}^B, p_{ij}\}$ that maximizes expected profit (4.1) subject to the set of constraints described in equations 4.2 and 4.3. The resulting pricing mechanism is incentive-compatible if it satisfies the following monotonicity conditions: $q_{HH}^A \geq q_{LH}^A$, $q_{HL}^A \geq q_{LL}^A$, $q_{HH}^B \geq q_{HL}^B$, and $q_{LH}^B \geq q_{LL}^B$. Intuitively, the monotonicity conditions say that the quantity of either good is weakly increasing with the corresponding valuation. Additionally, if in the resulting menu of contracts, the quantity of item i increases with the preference for component j, the seller is said to implement commodity bundling.

Definition 4.3.1 *In this model, the seller is said to implement* ***bundling*** *when, for a given menu of contracts, the quantity of product i increases with preference for product j, i.e. when* $q^A_{LL} < q^A_{LH}$*, and/or* $q^A_{HL} < q^A_{HH}$*, and/or* $q^B_{LL} < q^B_{HL}$*, and/or* $q^B_{LH} < q^B_{HH}$*.*

Bundling occurs when the probability mass function (PMF) of buyer types takes a specific form. The shape of the PMF depends on the correlation of preferences defined as $\rho = \beta_{HH}\beta_{LL} - \beta^2$. One of the main intuitions in the early screening literature is that it is in the seller's best interest to bundle the two products whenever the correlation of preferences is weak enough ([66], [63], and [61]). In this model, bundling is profitable as long as $\rho < \frac{\beta^2}{\beta_{LL}}$. For this paper's purposes, I will assume that $\rho < 0 < \frac{\beta^2}{\beta_{LL}}$, which is the case when the incentive to bundle is the strongest.

In a "relaxed" version of the problem, the seller ignores the possibility of lower types misrepresenting their preferences. In this version of the program, as long as the PC restriction for the LL-type is satisfied, she does not have to worry of the LL buyer purchasing any other package but his; thus, only the lowest participation constraint is relevant in the relaxed program. Additionally, in this simplified version of the problem, only the "downward" incentive restrictions are relevant. The seller does not consider the possibility of the HL-type choosing the packages intended for either the LH-type or the LL-types; similarly, she does not have to worry about the LH-type buyer choosing contracts designed to serve the HL and/or the HH-type. This problem is relaxed in the sense that it includes only a subset of all possible incentive and participation restrictions. In fact, only one participation and four incentive constraints are considered. The only important PC equation is that of the LL-type buyer, and if $R_{LL} \geq 0$, then all buyer types' PC constraints are satisfied. The relevant IC constraints are graphically depicted in figure 4.1. As I show later, the solution to the relaxed problem is the solution to the fully constrained program.

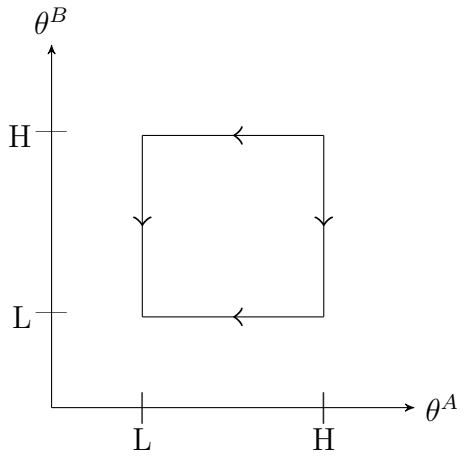


Fig. 4.1.: IC constraints in the relaxed problem

4.3.2 Optimal pricing without regulation

I now proceed to use the relaxed program to characterize the optimal menu of contracts both without and with portion cap. Without regulation, the seller's problem is to design a menu of contracts to maximize expected profit (4.1) subject to the set of PC and IC restrictions listed in 4.4.

$$
\begin{aligned}
&R_{LL} = 0 \\
&R_{LH} = u(q^B_{LL})\Delta \\
&R_{HL} = u(q^A_{LL})\Delta \\
&R_{HH} = \Delta[u(q^A_{LL}) + u(q^B_{LL})] + \max\{[u(q^A_{LH}) - u(q^A_{LL})]\Delta,\, [u(q^B_{HL}) - u(q^B_{LL})]\Delta,\, 0\} \\
&q^A_{HH} \geq q^A_{LH},\ q^A_{HL} \geq q^A_{LL},\ q^B_{HH} \geq q^B_{HL}, q^B_{LH} \geq q^B_{LL}
\end{aligned}
\tag{4.4}
$$

Where $\Delta \equiv \theta^H - \theta^L$. The first step in solving the seller's problem is to find out the exact form of the incentive-compatibility constraint for the HH-type buyer. To provide incentives to the HH-type to truthfully reveal his type, the seller must know which contract other than $\{q^A_{HH},\, q^B_{HH},\, p_{HH}\}$ could attract the HH buyer strongly enough for him to choose it. Given the correct prices, the HH-type could feel inclined

to purchase any of the other three contracts originally designed to serve the LH, HL, and LL-types. Intuitively, this is captured by the three arguments inside the brackets of the max expression in R_{HH} among the equations in 4.4.

Proposition 4.3.1 *The HH-type buyer incentive compatibility constraint is* $R_{HH} = \Delta[u(q^A_{LL}) + u(q^B_{LL})] + [u(q^A_{LH}) - u(q^A_{LL})]\Delta + [u(q^B_{HL}) - u(q^B_{LL})]\Delta$.

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

Assume that $R_{HH} = 2\Delta u(q_{LL})$, *this implies* $0 \leq q_{LH} - q_{LL}$. *Using this constraint, program 4.4 has the following First Order Conditions associated with* q_{LH} *and* q_{LL}*:*

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

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

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

The first order conditions characterizing the solution to the seller's problem without regulation are in 4.5.

$$\begin{cases} [q^A_{HH}] : \theta_H u'(q^A_{HH}) = c'(q^A_{HH}) \\ [q^B_{HH}] : \theta_H u'(q^B_{HH}) = c'(q^B_{HH}) \\ [q^A_{HL}] : \theta_H u'(q^A_{HL}) = c'(q^A_{HL}) \\ [q^B_{HL}] : \theta_H u'(q^B_{HL}) = \frac{c'(q^B_{HL})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta^L}\right)} \\ [q^A_{LH}] : \theta_L u'(q^A_{LH}) = \frac{c'(q^A_{LH})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta^L}\right)} \\ [q^A_{LL}] : \theta_L u'(q^A_{LL}) = \frac{c'(q^A_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta^L}\right)} \\ [q^B_{LL}] : \theta_L u'(q^B_{LL}) = \frac{c'(q^B_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta^L}\right)} \end{cases} \tag{4.5}$$

Naturally, the solution characterized by the FOC above is only relevant if it is the solution to the fully constrained problem. Below, I propose and prove this is the case. This proof closely follows that in [66].

Proposition 4.3.2 *Maximizing 4.1 subject to 4.4 gives the solution to the seller's fully constrained problem.*

Proof *Proposition 4.3.2. Together, $R_{LL} = 0$, the monotonicity constraints, plus the four binding constraints in 4.1 imply the satisfaction of the following omitted incentive constraints:*

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

From the first order conditions in 4.5 it is straightforward to conclude that $q_{HL} > q_{LH}$, thus:

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

Lastly, the single crossing condition implies:

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

■

In sum, without regulation, the quantities offered are such that:

- $q_{HL}^{A*} = q_{LH}^{B*}$, $q_{LH}^{A*} = q_{HL}^{B*}$, $q_{HH}^{A*} = q_{HH}^{B*}$, $q_{LL}^{A*} = q_{LL}^{B*}$.
- The quantities (q_{ij}^{A}, q_{ij}^{B}) purchased for each ij-type are: $(q_{HH}^{A*}, q_{HH}^{B*})$, $(q_{HL}^{A*}, q_{LH}^{B*})$, $(q_{LH}^{A*}, q_{HL}^{B*})$, and $(q_{LL}^{A*}, q_{LL}^{B*})$ for the HH, HL, LH, and LL-type respectively.
- The largest portions are $(q_{HH}^{A*} = q_{HH}^{B*} = q_{HL}^{A*} = q_{LH}^{B*})$. The medium options are $(q_{HL}^{B*} = q_{LH}^{A*})$. The small options are $(q_{LL}^{A*} = q_{LL}^{B*})$.
- Let $q_{HL} \equiv q_{HL}^{A} = q_{LH}^{B}$, $q_{LH} \equiv q_{LH}^{A} = q_{HL}^{B}$, and $q_{HH} \equiv q_{HH}^{m}$, $q_{LL} \equiv q_{LL}^{m}$, for $m = A, B$, the seller's value function is $\mathbb{E}[\pi(\cdot)^*]$, expressed in 4.6.
- Consumer rents are: $R_{LL} = 0$, $R_{LH} = \Delta u(q_{LL}^{B*})$, $R_{HL} = \Delta u(q_{LL}^{A*})$, and $R_{HH} = \Delta[u(q_{LL}^{A*}) + u(q_{LL}^{B*})] + [u(q_{LH}^{A*}) - u(q_{LL}^{A*})]\Delta + [u(q_{HL}^{B*}) - u(q_{LL}^{B*})]\Delta$.
- Because of the symmetry in the outcomes and to economize in space, I use the nomenclature q_{HH}^{*}, q_{HL}^{*}, and q_{LL}^{*} to denote the large, medium, and small unregulated options.

$$\begin{aligned}\mathbb{E}[\pi(\cdot)^*] = 2\Big\{ & \beta_{HH}\Big[\theta_H u(q_{HH}^*) - c(q_{HH}^*)] + \beta_{LL}[\theta_L u(q_{LL}^*) - c(q_{LL}^*)\Big] \\ & + \beta\Big[\theta_L u(q_{LH}^*) + \theta_H u(q_{HL}^*) - c(q_{LH}^*) + c(q_{HL}^*)\Big]\Big\} \\ & - \Delta\Big[(2\beta + \beta_{HH})u(q_{LL}^*) + \beta_{HH} u(q_{LH}^*)\Big]\end{aligned} \tag{4.6}$$

The profit-maximizing seller offers a menu of four package-price contracts, each of these targeting a specific type of buyer. That is, it is optimal to fully separate buyers by offering four options tailored to the taste of the four consumer types. To

visualize this screening strategy and to ease with the comprehension of the model's results, I graphically represent the separating scheme in figure 4.2. In this diagram, the solid black dots represent the buyers and their preferences can be inferred by their coordinates. For example, the lower-left dot represents the LL-type buyer, while the upper-right dot denotes the HH-type consumer. Different background colors represent different contracts. The figure thus shows that each buyer type purchases one of the four tailored packages.

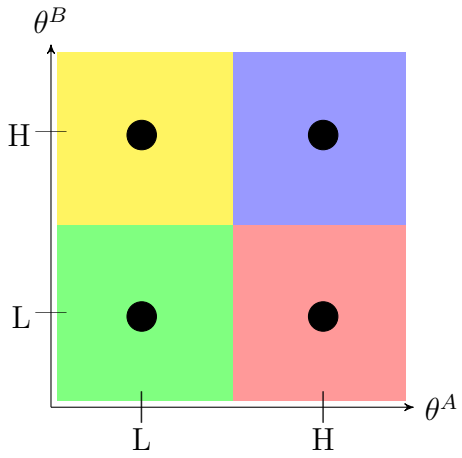


Fig. 4.2.: Optimal segmentation without regulation

To further aid with interpretation and comprehension of the theoretical hypotheses, In figures 4.3 and 4.4, I correspondingly show consumption (of both A and B) and consumer surplus by buyer type. I omit scale labels along the vertical axis of both figures because the specific values of these variables depend on the parametrization of the model. For some parameter combinations, for example, the LL-type is excluded from participation, and rents for the LL, LH, and HL types are null. However, the essence of the result remains. That is, consumption increases with type, bundling is observed in the form of larger sizes of product i when preference for good j rises, and consumer surplus increases weakly with buyers' preferences.

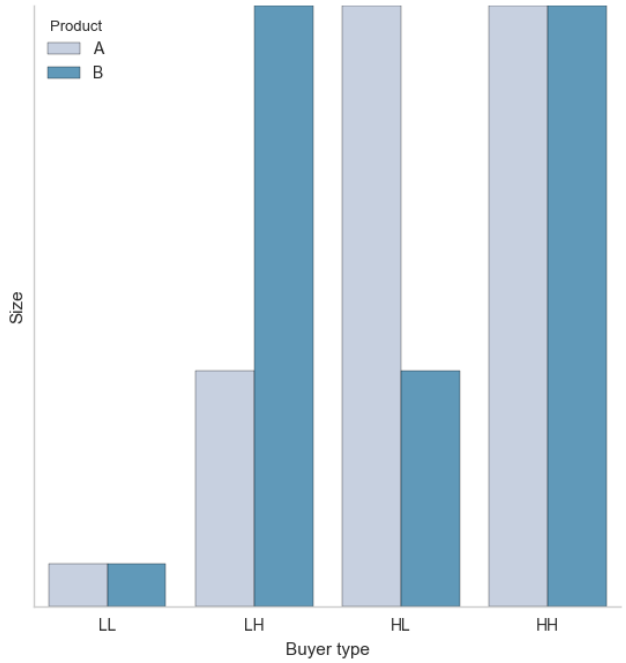


Fig. 4.3.: Graphical description of consumption by types (Theory) - Baseline

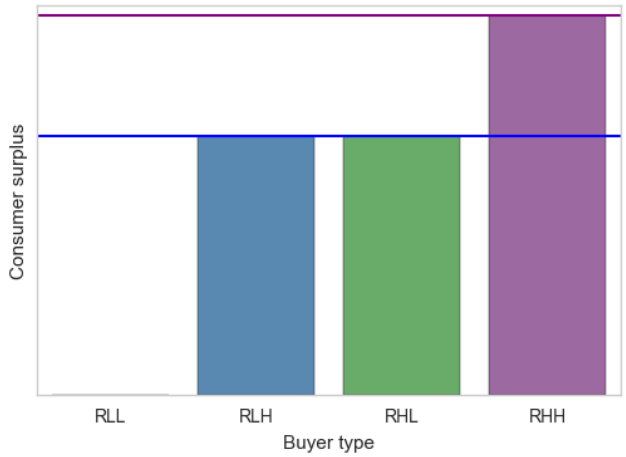


Fig. 4.4.: Graphical description of consumer surplus by types (Theory) - Baseline

4.3.3 Optimal pricing with portion cap rule

Without loss of generality, suppose that a cap is to be enforced on product A. The seller is not allowed to offer quantities of A larger than $\bar{q}$. Now, the seller's objective is to maximize 4.1 subject to the traditional participation (4.2) and incentive-compatibility (4.3) constraints, plus the following quantity cap (QC) restriction:

$$\text{QC: } q_{ij}^{A} \leq \bar{q} \text{ for } i, j = L, H \tag{4.7}$$

Restriction QC means that the seller is not allowed to sell quantities larger than $\bar{q}$ of product A to any ij-type buyer. A restriction where $\bar{q} \geq (q_{HH}^{*} = q_{HL}^{*})$ would be innocuous because it would not have an impact on the seller's optimal pricing scheme. Varying on restrictiveness, there are three economically interesting levels of severity at which the cap can be set:

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

Taking the unregulated quantities as benchmarks to design the policy, the regulation on the the portion of good A can be: 1) mild if the limit is set below the larger quantity available without regulation but above the quantity of the medium unregulated alternative; 2) moderate if the cap is set below the medium unregulated option but above the quantity contained in the smallest regulation-free alternative, or 3) harsh if the limit on quantity is set at a level lower than the small alternative without the cap. In this paper, I study the impact of a moderate restriction. The moderate restriction approximates the design of the portion cap rule proposed in 2012 in New York City, since the common small, medium, and large portion choices of soda normally found in American fast-food restaurants are 16, 21, and 32 ounces respectively; the proposed intervention would have enforced a maximum size of 16 ounces.

Equation 4.3 shows the general form of the IC restrictions and from this equation, using this equation, it can be shown that as the regulation causes both q^A_{HH}, and q^A_{HL} to become smaller, the extraordinary information rent that the LH-type would gain from posing as either HH or HL increases. In other words, as the quantity of product A becomes smaller due to more restrictive cap rules, the seller has to be aware of the possibility of the LH-type misrepresenting himself as an HL-type and increase the temptation payoff accordingly. With a moderate cap, the incentive constraint preventing unfaithful representation of the LH-type buyer as an HL-type is binding. This modification renders the downward incentive constraints involving the HH-type redundant. In other words, if the downward incentive constraints for the LH-type buyer are satisfied, the HH-type buyer will not purchase neither of the two contracts intended to serve the HL-type and the LL-type buyers. I graphically show the new set of IC conditions in figure 4.5. With a cap then, the seller maximizes her expected profit (4.8), subject to the LL-type buyer's PC, the set of incentive constraints listed in 4.9, and the moderate quantity constraint $(q^*_{HH} = q^*_{HL}) > q^*_{LH} > \bar{q} \geq q^*_{LL}$. The first order conditions that characterize the solution to this problem are in 4.10.

$$\begin{aligned}\mathbb{E}[\pi] = (\beta_{HH} + \beta)[\theta_L u(\bar{q}) + \theta_H u(q^B_{LH}) - c(\bar{q}) - c(q^B_{LH})] + \\ \beta[\theta_H u(\bar{q}) + \theta_L u(q^B_{HL}) - c(\bar{q}) - c(q^B_{HL})] + \\ \beta_{LL}[\theta_L u(q^A_{LL}) + \theta_L u(q^B_{LL}) - c(q^A_{LL}) - c(q^B_{LL})] - \\ \beta(R_{LH} + R_{HL}) - \beta_{LL} R_{LL}\end{aligned} \tag{4.8}$$

$$\begin{aligned}R_{LL} &= 0 \\ R_{HL} &= \Delta u(q^A_{LL}) \\ R_{LH} &= \Delta u(q^B_{LL}) + \Delta u(q^A_{LL}) - \Delta u(\bar{q}) + \Delta u(q^B_{HL}) \\ R_{HH} &= 2[\theta_H u(\bar{q}) + \theta_H u(q^B_{LH})] - \Delta[u(q^B_{LL}) + u(q^A_{LL}) + u(q^B_{HL})]\end{aligned} \tag{4.9}$$

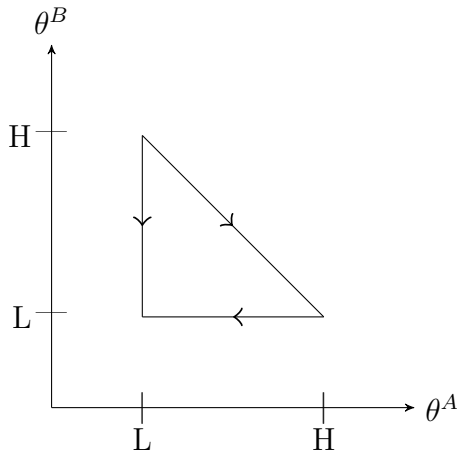


Fig. 4.5.: IC constraints in the relaxed problem with a portion cap

$$\begin{cases} [\bar{q}]: \quad \theta_H u'(\bar{q}) = c'(\bar{q}) \frac{\beta_{HH}+2\beta}{\left[\frac{\theta_L}{\theta_H}(\beta_{HH}+\beta)+\beta\left(1+\frac{\Delta}{\theta_H}\right)\right]} \\ [q^B_{LH}]: \quad \theta_H u'(q^B_{LH}) = c'(q^B_{LH}) \\ [q^B_{HL}]: \quad \theta_L u'(q^B_{HL}) = \frac{c'(q^B_{HL})}{1-\frac{\Delta}{\theta_L}} \\ [q^A_{LL}]: \quad \theta_L u'(q^A_{LL}) = \frac{c'(q^A_{LL})}{\left[1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right]} \\ [q^B_{LL}]: \quad \theta_L u'(q^B_{LL}) = \frac{c'(q^B_{LL})}{\left(1-\frac{\Delta}{\theta_L}\right)} \end{cases} \tag{4.10}$$

Let the endogenous variables that solve the conditions in 4.10 be referred to with the double star $(**)$ superscript. The results of a cap are:

- The HH-type, and LH-type buyers purchase the same contract with quantities $(\bar{q}^{**}, q^{B**}_{LH})$. The HL, and LL types consumer get quantities $(\bar{q}^{**}, q^{B**}_{HL})$, and $(q^{A**}_{LL}, q^{B**}_{LL})$.
- Importantly, it can be shown that: $q^{B**}_{LH} = q^{B*}_{LH}$; $q^{B**}_{HL} < q^{B*}_{HL}$; and $q^{B**}_{LL} > q^{B*}_{LL}$.
- $q^{A**}_{LL} < \bar{q}$; $q^{B**}_{LL} < q^{B**}_{HL} < q^{B**}_{LH}$.
- Consumer rents compare as follows: $R^{**}_{LL} = R^{*}_{LL}$; $R^{**}_{HL} = R^{*}_{HL}$; $R^{**}_{LH} > R^{*}_{LH}$, and $R^{**}_{HH} < R^{*}_{HH}$.

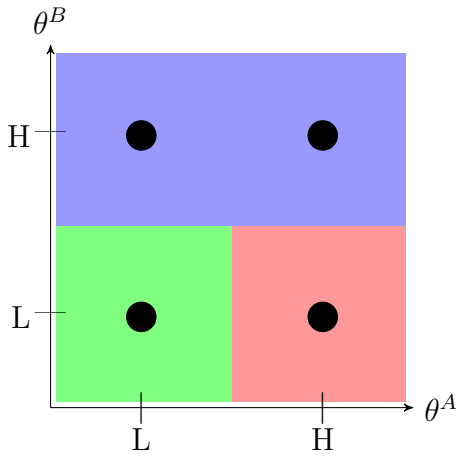


Fig. 4.6.: Optimal segmentation with cap

- The seller's value function is $\mathbb{E}[\pi(\cdot)^{**}]$, expressed in 4.11. It can be shown that $\mathbb{E}[\pi(\cdot)^{**}] < \mathbb{E}[\pi(\cdot)^{*}]$

$$\begin{aligned}\mathbb{E}[\pi(\cdot)^{*}] = (\beta_{HH} + \beta)[\theta_L u(\bar{q}) + \theta_H u(q^B_{LH}) - c(\bar{q}) - c(q^B_{LH})] + \\ \beta[\theta_H u(\bar{q}) + \theta_L u(q^B_{HL}) - c(\bar{q}) - c(q^B_{HL})] + \\ \beta_{LL}[\theta_L u(q^A_{LL}) + \theta_L u(q^B_{LL}) - c(q^A_{LL}) - c(q^B_{LL})] - \\ \beta(R_{LH} + R_{HL}) - \beta_{LL} R_{LL}\end{aligned} \tag{4.11}$$

The resulting optimal segmentation strategy with a moderate cap is depicted in figure 4.6. The portion cap results in bunching of HH and LH-type buyers; these type of customers purchase the same contract. This differs from the baseline environment with no regulation where the LH and HH-types are offered the same large portion of product B, but different quantities of product A.

Because in the model the two products are neither complements nor substitutes, it is surprising to find that the theoretical results suggest changes for the quantity of the *unregulated* product B purchased by the HL and LL-type buyers. According to the theoretical outcomes associated with a moderate restriction, the HL-type buyer is offered less of product B, while the LL receives *more* of it. This result stems from the nature of the incentive-design problem faced by the seller. Once the cap

is implemented, her desire to price-discriminate continues and the restriction merely reduces her choice space. To accommodate the policy while at the same time continue to adopt a profit-maximizing segmentation strategy, the seller has to modify all of the endogenous variables to her disposal, including the quantities of product B. I continue with a brief explanation of the forces driving these adjustments.

I first discuss the adjustments made to the small package designed to serve the LL-type buyer. In essence, these changes are driven by the LL-type's participation constraint and the need to provide positive rents to the LH-type for him to purchase his own package. Without regulation, information rents for the LH-type take the form of a larger quantity of product A compared to the level received by the LL-type buyer. With a moderate cap on A, the LH-type (as well as the HL, and HH types) consumes less of the regulated product A. However, the profit-maximizing seller still needs to provide positive information rents to the LH-type in order to make sure that this buyer will not purchase the small combo designed to serve the LL buyer. Because there is an external limit on A, the only way the seller can increase the difference in quantity of A offered to the LL and LH types is by decreasing the quantity of A served to the LL-type buyer. Thus, the LL ought to receive less product A. To maintain the satisfaction of the LL-type's participation constraint, the seller increases the quantity of component B served to this type. This explains the change in the mix of A and B served to the LL-type consumer.

I now turn to explain the modifications in the package sold to the HL-buyer. In essence, these are explained by the changes in the smallest package (served to the LL-type consumer), and the fact that the need to separate the HL from the LL-type remains, but the incentives need not be as strong under regulation. Due to the cap, the seller is unable to offer the first best quantity of product A to the HL-type buyer. Indeed, because the cap is of moderate nature, the HL buyer purchases considerably less compared to the baseline. The seller still needs to provide incentives to the HL-type in the form of a larger portion of product B compared to the LL package. Because the quantity of product A contained in the smallest package (that serving

the LL-type) is low and indeed smaller compared to the baseline unregulated case, the extra amount of product B granted to the HL-type consumer to generate information rents need not be as large. This explains the reduction in consumption of product B from the HL-type buyer.

Regarding the impacts on buyers' surplus, the model predicts two main impacts on consumer surplus contingent on the type of the buyer: a reduction in the rents granted to the HH-type (R_{HH}) and an *increase* in the surplus earned by the LH-type (R_{LH}). The reason behind the reduction of the HH-type's surplus is straightforward. The HH-type buyer is worse-off because he is receiving significantly less of a product he values highly and the reduction in price is not large enough to compensate for the diminished size of the package. The intuition behind the increase in the LH-type's well-being is the following. In the unregulated baseline, the LH-type is purchasing a "medium" portion product A for which he has a low preference. The LH buyer would prefer a "small-large" A-B combo which is not available in the baseline menu of choices. The portion cap rule moves the choice set closer to ideal for this buyer type because it reduces the quantity of product A he is offered. Therefore, this buyer purchases less of the product for which he has a low preference, while still consuming a large portion of the product he values highly.

To help with the interpretation of the theoretical outcomes, I include figures 4.7 and 4.8 which correspondingly depcit consumption and consumer surplus patterns when under a moderate portion cap rule enforced on product A. In figure 4.7 the horizontal red line indicates the maximum-quantity limit on product A. In figure 4.8, the purple and blue horizontal lines indicate the baseline levels for HH-type and LH-type consumer surplus, respectively. In both figures, I omit the scale in the vertical axis because the point value of each column is contingent on the model's parametrization. In some cases, for example, the LL-type is excluded from participation, and rents for the LL, and HL types are null. However, the essence of the result remains: the model predicts that a severe enough cap on A will reduce consumption of A; increase con-

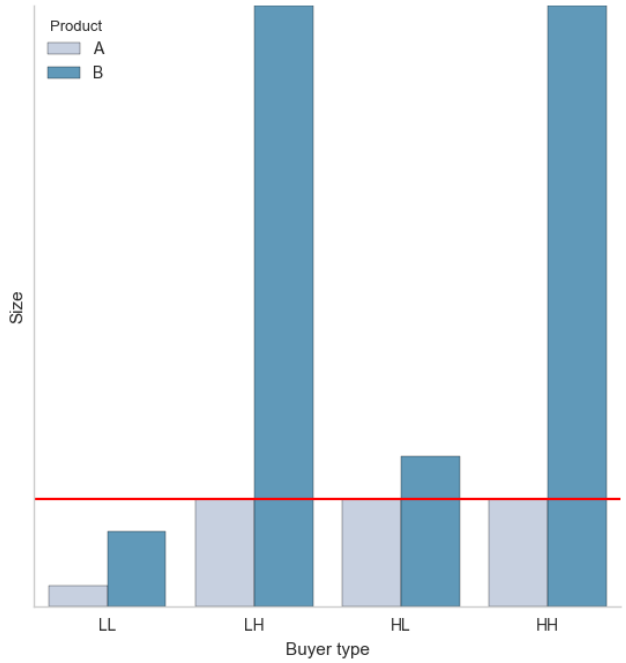


Fig. 4.7.: Graphical description of consumption by types (Theoretical) - Cap

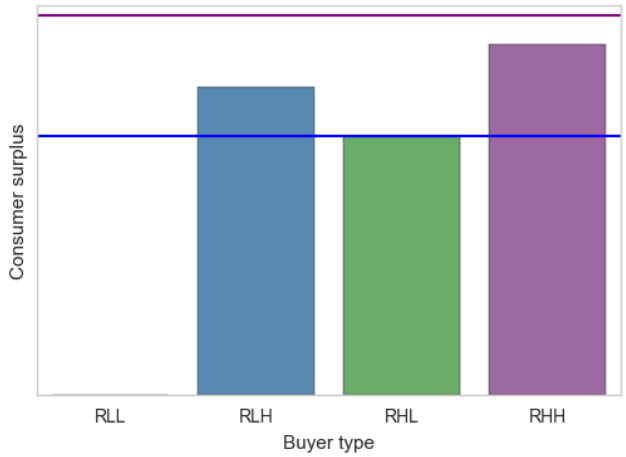


Fig. 4.8.: Graphical description of consumer surplus by types (Theoretical) - Cap

sumption of B by the LL buyer; decrease consumption of B by the HL type; increase consumer surplus for the LH-type, and reduce consumer rents for the HH-type.

4.3.4 Hypotheses

The subsections above characterize the effects of the cap as predicted by a standard multidimensional nonlinear pricing model. I summarize these results in the hypotheses below. These constitute the set of hypotheses I will test in a controlled experiment.

***Hypothesis** 6. Consumption of good A.* Following the implementation of a portion cap rule on product A, all buyer types reduce their consumption of the regulated product A.

***Hypothesis** 7. Consumption of good B.* Implementing a portion cap rule on product A will result in the following impacts on consumption of good B: i) the LH and HH-type buyers do not reduce their consumption of the unregulated product B; ii) the HL-type purchases less of B, and iii) the LL-type buyer consumes more of product B.

***Hypothesis** 8. Expected profit and consumer rents.* Imposing a cap on product A will cause the following impacts on surplus: i) the seller's expected profit is smaller; ii) the LH-type receives more consumer surplus; iii) the HH-type buyer earns a smaller consumer rent, and iv) the LL and HL-type's consumer surpluses remain unaffected.

The next step before conducting an experiment to test these predictions is to choose a parameter constellation for the model. In table 4.1, I display the parameters I use during the experiment. With this parametrization, without a cap, the optimal scheme excludes the LL-type and offer distinct options to each of the other buyer types. The chosen probability combination of buyer types is fairly generic, its properties are not particular and can be considered to be fairly representative of other probability-combinations with negative correlation. In figure 4.9, the 2-simplex in

the upper panel shows all possible combinations of probabilities I could have selected. The coordinates within the lightest area correspond to values where $0 < \frac{\beta^2}{\beta_{LL}} < \rho$, and the seller has no incentive to engage in bundling. Coordinates in the second lightest area of the 2-simplex correspond to values of probabilities where $0 < \rho < \frac{\beta^2}{\beta_{LL}}$, thus the incentive to bundle is "weak". The incentive to bundle is the strongest in the dark blue area where $\rho < 0 < \frac{\beta^2}{\beta_{LL}}$. The red line highlights "symmetric" combination of probabilities where $\beta_{HH} = \beta LL$. The combination of probabilities I chose is generic and lies relatively far from "border" and corner regions in the 2-simplex. Moreover, since it is symmetric (the probability of the buyer being a LL-type is the same with the probability of being an HH-type) and it can be expressed with probabilities with only one decimal, this distribution reduces the complexity of the experimental instructions.

Table 4.1.: Parameter values used in this study

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

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

4.4 Experimental design

In total, 82 subjects were randomly assigned to one of two experimental treatments. I refer to the treatments as either *Baseline* or *Cap* depending on their policy environment. There were three sessions per treatment with 12 to 14 subjects each. Sessions were conducted between October and November of 2017 at Purdue Univer-

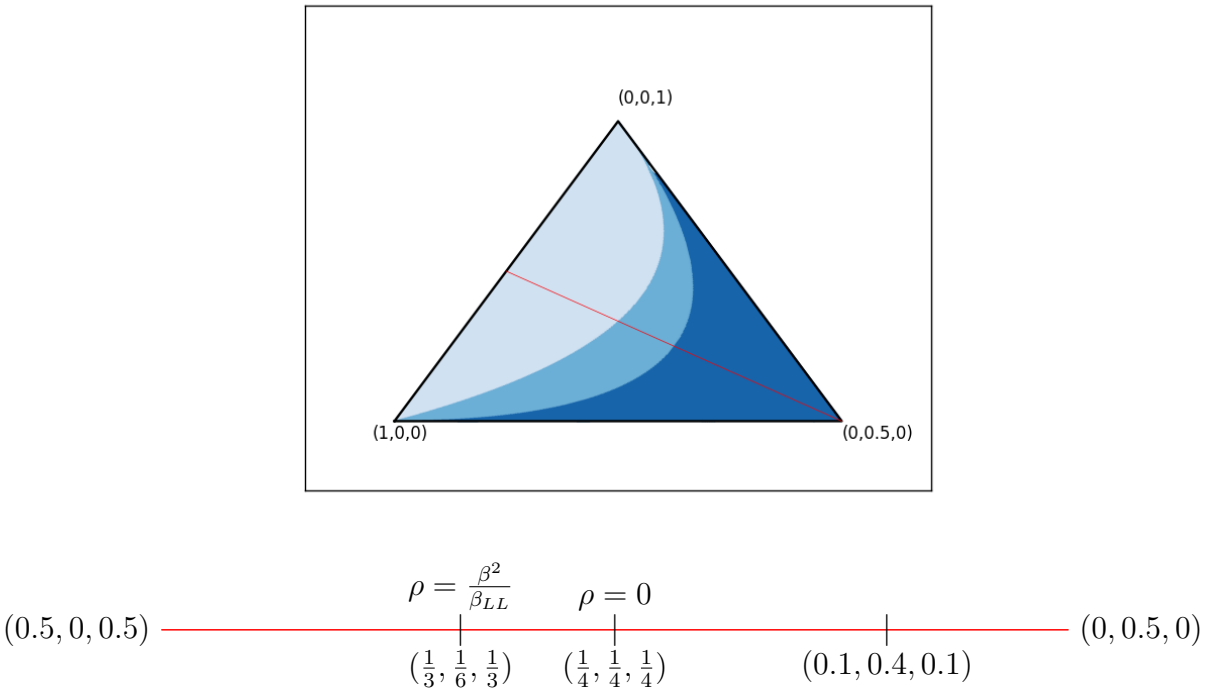


Fig. 4.9.: Chosen probabilities of buyer types

sity's Vernon Smith Experimental Economics Laboratory. Payoff functions and the ranges of choice variables given to the subjects can be seen in table 4.2. Subjects were recruited via ORSEE [53]. The experimental interface was designed with oTree [54]. The instructions were read aloud by a computer using Google's text to speech application programming interface gTTS 1.2.2. No subject participated in more than one session.

Table 4.2.: Experimental treatments

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

In all sessions, subjects play "trading periods" in which the seller submits a menu of choices and the buyer makes consumption decisions. Subjects play 6 "training periods" with no financial consequences which allows them to become familiar with the interface and the periods' structure. Following the training phase, each subject plays 11 paying "trading periods". Every menu of choices submitted and the corresponding purchase decision constitute an observation in my database. Excluding training periods, the final database contains 902 observations, 440 from the *Baseline* group and 462 from the *Cap* treatment. All subjects are assigned to the role of a seller and did not interact with any other human subject in the room. The role of the buyer was taken by a computer program behaving as a rational utility-maximizing buyer. The buyer type was randomly and independently assigned each trading period. Throughout the experiment, earnings were denominated in points. Final earnings were converted into cash at the exchange rate was 31 points per US Dollar. All sessions had the same structure: first, subjects answered a pre-experimental quiz; second, there were six "training" non-paying trading periods; then, eleven "effective" trading rounds were played; lastly, subjects answered a post-experimental survey. Four out of the eleven effective periods were randomly selected to determine subjects' final payoff consisting of the sum of points earned in the chosen periods. Subjects were informed of all the above plus the profit and information rents functions before the beginning of the session. I append the computer interface's screens and instructions for the *Cap* treatment at the end of the paper.

The game in each trading period closely mirrors the screening problem I describe in the previous sections. At the beginning of each trading round, the seller chooses to offer a number of packages, from one to four; she can also choose not to offer any package at all. Next, the seller specifies quantities and prices. Thus, the seller is designing a menu consisting of up to four packages, each with three arguments: quantity of product A, quantity of product B, and price. Following the design of the menu, the offer is submitted to the computerized buyer for consideration. The buyer can purchase only one package per period. The buyer chooses the package that

maximizes his payoff, but rejects the entire menu if all packages resulted in earnings lower than the reservation value of zero. If more than one packages results in the same non-negative earnings for the buyer, then the first of these packages (in the order they were submitted by the seller) is chosen. The seller and buyer payoffs in points are determined using the purchased package, if any. If no menu is submitted or if the buyer rejects the entire menu, both parties receive zero points. At the end of each trading period, the seller is shown the terms of the menu she offered, the choice made my the seller and her period earnings in points. Subjects also have access to a calculator during the menu-design phase of the trading periods. With this calculator, subjects can experiment with different quantities-price combinations and learn how these would translate into profit, cost of production, and consumer surplus per buyer type.

The sum of points earned in four out of the eleven effective trading periods determined the final experimental earnings for the seller. These were randomly chosen via the following protocol. Labeled from 1 to 330, the experimenter had a list with all possible combinations of four periods. A computer application that randomly chooses numbers between 1 to 330, all equally likely. The application was activated three time. The number that appeared the third time represented the label of the selected combination of paying periods. This was done before subjects started to answer the pre-experimental quiz. The selected paying combination was shown to each subject after they finished with all of their tasks. If the sum of the four randomly selected periods was negative, the earnings of the subject was set to zero.

4.5 Results

4.5.1 Descriptive overview

Before introducing the main results of the study, I first offer an overview of the general patterns found in the data. I present evidence suggesting that subjects submit offers consistent with nonlinear pricing theory. This would grant a degree of confidence

that my experimental design appropriately captures the essence of the theory, and that subjects understood the instructions.

Specifically, the theory predicts that, without regulation, sellers engage in bundling when facing privately informed buyers where the distribution of types is negatively correlated. If I take all of the menus with one or more packages submitted during the baseline treatment, order the packages within a menu by the sum of their quantities, and average across menus, the result is figure 4.10. Remember that bundling is said to exist if the quantity of product j increases with preference for component i, and this is graphically confirmed in figure 4.10, assuming that the smaller, and second smaller packages target LL and LH types, while the largest and the second largest target HH and HL types, respectively. This is a crude approximation to the sellers' pricing scheme in the sense that it is not immediately obvious which of the two "medium" packages (the options between the smallest and the largest) would be consumed by either the HL or the LH type. Moreover, it ignores the possibility that some sellers engaging in bunching (serving more than one type with a single package), and exclusion. However, it is not one of my objectives to formally test the theory of multidimensional screening. Therefore, I consider the pattern of offered quantities shown in figure 4.10 to be evidence of sellers attempting to bundle.

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

To elicit segmentation and price discrimination, subjects were informed that they were going to be matched with a single buyer each trading round but the type of the buyer would change across periods according to a known vector of probabilities. From the submitted menus, I can infer which packages would each type of buyer would have purchased had he been presented with the submitted menu. These packages and their associated payoffs are the data I use to test hypotheses during the rest of this

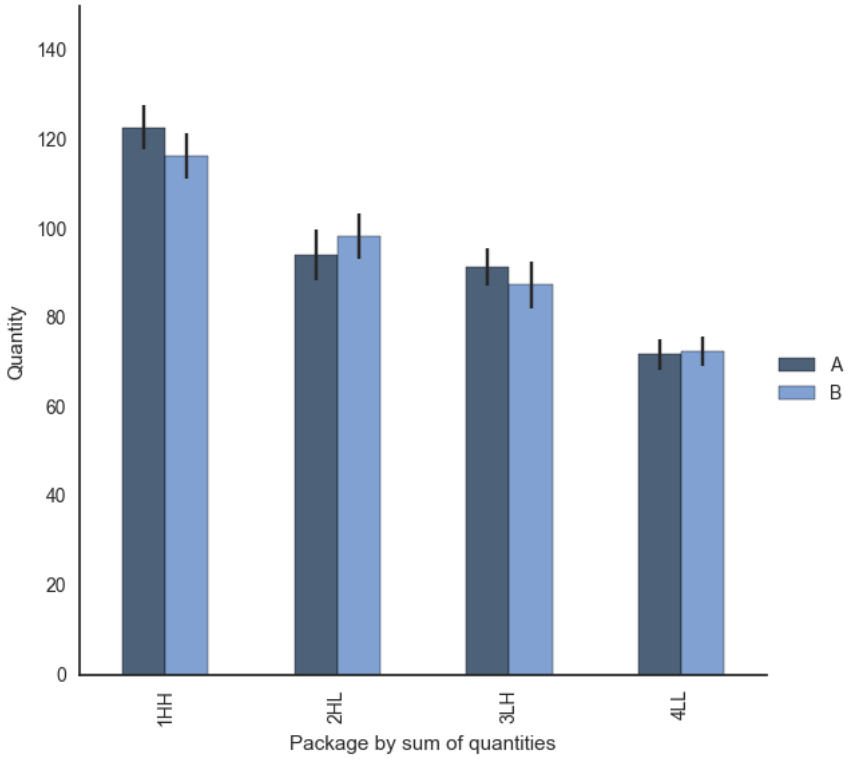


Fig. 4.10.: Packages by sum of offered quantities: Baseline

document. Tables 4.3, and 4.4 show average price and quantities of the packages purchased by each buyer type in the baseline and cap treatments, correspondingly. In both treatments, price and quantities are larger in later periods.

Table 4.3.: Average paid prices and purchased quantities per buyer type: Baseline treatment

	Buyer type			
	LL	LH	HL	HH
All periods:				
Mean price	160.14	209.66	211.35	218.80
Mean q^A	93.27	98.32	117.15	114.02
Mean q^B	90.58	112.93	97.11	109.84
First 5 periods:				
Mean price	145.49	197.63	200.18	204.39
Mean q^A	84.82	92.07	112.38	105.95
Mean q^B	83.47	107.98	91.26	103.87
Last 6 periods:				
Mean price	173.66	219.69	220.75	230.57
Mean q^A	101.06	103.53	121.16	120.60
Mean q^B	96.83	117.05	102.03	114.71

Table 4.4.: Average price and quantities per buyer type: Cap treatment

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

The evolution in prices and quantities would be evidence of a greater degree of pricing sophistication if buyers' information rents are lower in later periods and seller's per-period payoffs are larger later in the experiment. Tables 4.5 and 4.6 show that this is generally the case. As the experiment progresses, subjects seem to learn to more precisely price their packages and extract more surplus from the buyers as a result.

Subjects do not seem to explore with different segmentation strategies, rather they seem to adopt a strategy and increase their sophistication for that scheme. If subjects were switching their segmentation schemes, I would expect the participation of buyers (especially the lowest type) to vary as subjects may decide to exclude them some times and cover them during other trading rounds. Table 4.7 shows that within and across treatments, the market coverage patterns observed in the early part of the experiment are also appreciated later on. That is, the fraction of menus that cover a given buyer type remained stable during the experimental sessions and the market coverage profile observed in the baseline group closely approximates the appreciated in the cap treatment. In addition to the results shown above supporting increased surplus extraction in later periods, This suggests that, on average, subjects did not switch between segmentation strategies, rather they choose a segmentation pattern increased their pricing accuracy as the sessions progressed.

4.5.2 Major results

I now continue with the paper's main research objectives, namely finding what are the impacts that a moderate cap on product A has on quantity consumed of both products and on consumer surplus by buyer type. For all menus of contracts that subjects submitted during the trading periods, I infer which package each type of buyer would have purchased; how much they would have paid; the seller's expected profit; the information rents for all buyers, and the associated experimental payoffs in points. I use these quantities in the estimations below.

Table 4.5.: Average per-period earnings: Baseline treatment

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

Table 4.6.: Average per-period earnings: Cap treatment

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

Table 4.7.: Market coverage: Participation by buyer type

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

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

I start by looking at the impacts on quantity purchased by type of buyer. In table 4.8, I show econometric estimates of the portion cap's impact on quantities purchased by each buyer type. I find significant reductions in consumption of A by all buyer types. I do not find statistically significant evidence of a change in consumption of product B by any of the consumer types. These are the main two findings regarding impacts on consumption.

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

Main Result *1. According to hypothesis 6, compared to the unregulated baseline, all consumers reduce their consumption of product A.*

Main Result *2. According to hypothesis 7, the cap rule does not impact the quantity of product B purchased by the HH and LH-type buyers. In opposition to hypothesis 7, the HL-type buyer do not reduce his consumption of B. Although the LL-type's consumption of B is estimated to have the predicted sign, it is not statistically significant.*

Table 4.8.: Estimates: impact of the quantity cap on per-period quantities purchased per buyer type

	q^A_{HH}	q^B_{HH}	q^A_{HL}	q^B_{HL}	q^A_{LH}	q^B_{LH}	q^A_{LL}	q^B_{LL}
Cap dummy	-58.154***	7.580	-61.201***	0.468	-49.206***	7.454	-44.567***	9.480
	(8.936)	(12.141)	(9.788)	(9.560)	(8.729)	(12.102)	(5.779)	(9.374)
Period	1.705***	1.534***	1.298***	1.699***	1.541***	1.514***	1.940***	1.984***
	(0.385)	(0.484)	(0.230)	(0.368)	(0.462)	(0.453)	(0.444)	(0.656)
Constant	103.164***	100.327***	108.999***	86.411***	88.453***	103.329***	71.523***	70.542***
	(8.347)	(7.926)	(8.511)	(6.500)	(5.721)	(10.434)	(3.824)	(7.203)
Observations	896	896	872	872	890	890	467	467

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

I turn now to the distributional impacts of the portion cap rule. I show the econometric estimates of the impact on producer and consumer surpluses in table 4.9. The main hypotheses are that the LH-type is better off after the cap, while the HH is worse off. To complement the analysis the table also shows the impact on seller's expected profit and per-period profit (observed profit).

Main Result *3. In opposition to hypothesis 8: expected profit is not significantly smaller with a cap, and the reduction in consumer surplus earned by the HH-type buyers is not statistically significant either. In alignment with hypothesis 8, on the other hand, the LH-type buyer earns a larger surplus, while the HL and LL-type's surpluses remain unchanged.*

As predicted by the model, the LH-type is better off after the cap. Intuitively, this buyer is no longer pressed to buy more of the product he has a low valuation for in order to get the large portion of the good he values the most. The cap moves the set of options closer to the ideal for this buyer's preferences. Contrary to the hypotheses derived from the model, the HH-type buyer is not impacted by the cap. The main reason can be found in table 4.10. The HH-buyer is buying less of A a good he values largely, however he is also paying less for the package he is purchasing, the reduction in price compensates for the reduction in consumption.

Table 4.9.: Estimates: impact of the quantity cap on per-period earnings

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

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

Table 4.10.: Estimates: impact of the quantity cap on per-period prices

	p_{HH}	p_{HL}	p_{LH}	p_{LL}
Cap dummy	-34.163*	-42.081**	-29.174	-18.345
	(19.122)	(19.758)	(18.541)	(15.219)
Period	3.355***	3.291***	3.269***	3.596***
	(0.680)	(0.572)	(0.624)	(0.792)
Constant	198.185***	191.023***	189.076***	118.163***
	(16.693)	(16.926)	(16.496)	(13.467)
Observations	896	872	890	467

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

To put the empirical results in perspective, it is useful to compare them with the nonlinear pricing model's predictions. The first theoretical hypothesis I turn to is that of the changes in the quantities purchased by the LL-type buyer. For the LL buyer, the model predicts a reduction in the portion of A and an increase in the portion of B. As shown in table 4.8, I do observe a statistically significant reduction in quantity of product A purchased by the LL-type buyer (q^A_{LL}), which aligns with the hypothesis. On the other hand, although the estimated coefficient on the change of consumption of good B by this buyer type (q^B_{LL}) is positive as predicted, it is not statistically significant. As predicted by the model however, these changes in the mix of quantities consumed by the LL-type result in a null impact on his consumer rents (table 4.9). Because the price paid by this buyer type remained unaffected across treatments, as can be seen in table 4.10, the LL-type's rents are held constant via modifications in quantities, as opposed to a drop in price.

Recall that the model predictions regarding the consumption choices made by the HL-type are that this buyer would reduce his consumption of both products when the cap is enacted compared to the unregulated baseline. The empirical estimates displayed in table 4.8 suggest that this buyer does reduce his consumption of product A (q^A_{HL}), but do not modify his purchases of product B (q^B_{HL}). The nonlinear pricing

model predicts a null impact on the information rents earned by this buyer and this what I find in the data (see table 4.9). Because the cap limits the consumption of the product for which this consumer has a high valuation, in order to keep his consumer surplus unchanged, the seller must decrease the price of the package she offers to him. According to table 4.10, this is what subjects in the laboratory did.

The surprising result of an increased surplus earned by the LH-type buyer following a cap is also documented by the data, as the reader can see in table 4.9. Looking at the estimates in tables 4.8 and 4.9, I conclude that the increase in surplus is entirely explained by the reduction in the portion of product A acquired by this buyer (q^A_{LH} the product for which this buyer has a low valuation). This is because only the consumption of good A changed; neither the quantity consumed of the product B (q^B_{LH}) for which this buyer has a higher valuation changed nor the price paid per package registered statistically significant changes.

The nonlinear pricing model generated the following hypotheses regarding the HH-type consumer's consumption and surplus: lower quantity of A q^A_{HH}, no effect on consumed quantity of B q^B_{HH}, and therefore a lower consumer surplus R_{HH}. In the experimental data I find support for the predictions involving quantities (see table 4.8). Surprisingly, however, there is not a significant reduction in the surplus earned by this customer, as the reader can see in table 4.9. This is because, during the experiment, this buyer paid lower prices (see table 4.10) and the reduction is large enough to keep his information rents constant compared to the unregulated treatment.

4.6 Conclusion

In this paper, I present an economic analysis of a form of regulation that limits the maximum default quantity of one of the goods a multiproduct seller offers. In the context of food policy design, such interventions are known as portion cap rules. Cap rules are an alternative tool for policy makers to regulate the consumption of certain foods and ingredients judged to have deleterious impacts on human health

when consumed liberally. To analyze the economic outcomes of the regulation I look at a two-product seller facing demand from privately-informed buyers. When implemented, the cap is enforced on only one of the goods offered by the seller. I use a bi-dimensional nonlinear pricing model to derive predictions about the effects of the cap on the consumption of both items, consumer surplus, and expected profit. In the model, there are four types of privately-informed buyers in the market. The ij-type buyer has preference i for good A, and j for B. Preferences for a given product can be either high (H) or (L). The seller designs a menu of packages crafted to maximize her expected profit in this market characterized by adverse selection.

In the unregulated baseline, the model predicts the seller offers each of the products in "small", "medium", and "large" sizes. The menu of packages is designed such that the LL, LH, HL and HH buyers consume the following corresponding combination of goods A and B portions: small-small, medium-large, large-medium, and large-large. The consumers' information rents weakly increase with their valuation for the products. The pricing model predicts that a portion cap rule limiting the quantity of A to be below the "medium" unregulated portion but larger than the "small" alternative would result in: i) less consumption of the regulated product for all buyers; ii) increased consumption of the unregulated product for the LL-type buyer; iii) reduced consumption of the unregulated product for the buyer with high preference for the regulated good and low preference for the unregulated good; iv) larger consumer surplus for the buyer with low preference for the regulated item and high preference for the unregulated good, v) lower consumer rents for the buyer type with high preference for both products, and vi) no change in consumer surplus for the other buyers. The experimental data confirms the reduction in purchased portions of good A, the increase in buyer surplus by the HL-type consumer, and the null impact on the consumer surplus earned by the LL and HL-type buyers. There is no significant changes in consumption of product B for any buyer type. All buyer rents, with the exception of the LH-type's surplus, remain unaffected.

Thus, the experimental evidence suggests that a moderate portion cap rule would be successful at reducing consumption of the targeted product from all consumer types, with neither increased consumption of the unregulated component nor negative impacts on consumer well-being. Indeed, one type of buyer is better-off as a result of the policy, namely the consumer with low valuation for the regulated product A and high preference for good B. If available, this buyer would prefer a price-discounted "small-large" A-B package; the closest option for them in the unregulated baseline is a price-discounted "medium-large" combo; the "small-small" alternative has too little of product B, while the "large-large" package is just too expensive for this buyer. A portion cap rule on good A shapes the set of contracts such that the package designed by the seller to serve the buyers with low-high valuation, is closer this buyers' ideal contract. The buyer with high-high valuations for the A-B goods are surprisingly not worse-off after the policy, this is because during the experimental sessions, this type of buyer paid lower prices for the packages he purchased, the reduction in per-package price is significant and would have left information rents for this buyer unmodified after the cap.

These results have implications for food policy discussions around portion cap rules and similar measures. The assumption that portion cap rules negatively impact consumer well-being is an important driver of public discourse surrounding food policy and at it is already shaping public policy, as demonstrated by Mississippi's bill 2687 (2013). I show that these worries are not justified. A portion cap can increase consumer well-being for some buyers. The benefited benefited buyers have low valuation for the regulated product but high preference for the unregulated goods. Absent a portion cap rule, the seller has an incentive to engage in commodity bundling and offer to these buyers information rents in the form of a relatively larger quantity of the product he values lowly. The cap reduces the extent to witch bundling can be leveraged as a sorting device.

REFERENCES

REFERENCES

[1] C. L. Ogden, M. D. Carroll, and K. M. Flegal, "Prevalence of obesity in the United States," *JAMA*, vol. 312, no. 2, pp. 189–190, 2014.

[2] J. P. MacEwan, J. M. Alston, and A. M. Okrent, "The consequences of obesity for the external costs of public health insurance in the United States," *Applied Economic Perspectives and Policy*, vol. 36, no. 4, pp. 696–716, 2014.

[3] E. A. Finkelstein, J. G. Trogdon, J. W. Cohen, and W. Dietz, "Annual medical spending attributable to obesity: payer-and service-specific estimates," *Health Affairs*, vol. 28, no. 5, pp. w822–w831, 2009.

[4] J. Cawley and C. Meyerhoefer, "The medical care costs of obesity: An instrumental variables approach," *Journal of Health Economics*, vol. 31, no. 1, pp. 219–230, 2012.

[5] R. H. Lustig, L. A. Schmidt, and C. D. Brindis, "Public health: the toxic truth about sugar," *Nature*, vol. 482, no. 7383, pp. 27–29, 2012.

[6] World Health Organization, *Fiscal policies for diet and prevention of noncommunicable diseases: technical meeting report, 5-6 May 2015, Geneva, Switzerland.* World Health Organization, 2016.

[7] V. S. Malik, M. B. Schulze, and F. B. Hu, "Intake of sugar-sweetened beverages and weight gain: a systematic review," *The American Journal of Clinical Nutrition*, vol. 84, no. 2, pp. 274–288, 2006.

[8] V. S. Malik, B. M. Popkin, G. A. Bray, J.-P. Després, W. C. Willett, and F. B. Hu, "Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: A meta-analysis," *Diabetes care*, vol. 33, no. 11, pp. 2477–2483, 2010.

[9] K. L. Stanhope, "Sugar consumption, metabolic disease and obesity: The state of the controversy," *Critical reviews in clinical laboratory sciences*, vol. 53, no. 1, pp. 52–67, 2016.

[10] A. Jones, J. L. Veerman, and D. Hammond, "The health and economic impact of a tax on sugary drinks in Canada," *Hearth & Stroke Institute*, 2017.

[11] USDA, "What are added sugars?" https://www.choosemyplate.gov/what-are-added-sugars, 2017, (Accessed on 04/15/2017).

[12] G. A. Bray, S. J. Nielsen, and B. M. Popkin, "Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity," *The American Journal of Clinical Nutrition*, vol. 79, no. 4, pp. 537–543, 2004.

[13] World Health Organization, *Fiscal policies for diet and prevention of noncommunicable diseases: technical meeting report, 5-6 May 2015, Geneva, Switzerland.* World Health Organization, 2016.

[14] ——, "Guideline: Sugars intake for adults and children. 2015," *Available: http://www.who.int/nutrition/publications/guidelines/sugars_intake/en*, 2014.

[15] Y. Anwar, "Soda tax linked to drop in sugary beverage drinking in berkeley - berkeley news," http://news.berkeley.edu/2016/08/23/sodadrinking/, August 2016, accessed on 10/01/2016.

[16] A. Aubrey, "Taxing sugar: 5 things to know about philly's soda tax : The salt : Npr," http://www.npr.org/sections/thesalt/2016/06/09/481390378/taxing-sugar-5-things-to-know-about-phillys-proposed-soda-tax, June 2016, accessed on 10/01/2016.

[17] ——, Souring On Sweet? Voters In 4 Cities Pass Soda Tax Measures. *The Salt : NPR.* Retrieved from http://www.npr.org/sections/thesalt/2016/11/09/501472007/souring-on-sweet-voters-in-4-cities-pass-soda-tax-measures, November 2016.

[18] J. Falbe, N. Rojas, A. H. Grummon, and K. A. Madsen, "Higher retail prices of sugar-sweetened beverages 3 months after implementation of an excise tax in berkeley, california," *American Journal of Public Health*, vol. 105, no. 11, pp. 2194–2201, 2015.

[19] J. Falbe, H. R. Thompson, C. M. Becker, N. Rojas, C. E. McCulloch, and K. A. Madsen, "Impact of the Berkeley excise tax on sugar-sweetened beverage consumption," *American Journal of Public Health*, vol. 106, no. 10, pp. 1865–1871, 2016.

[20] J. Grogger, "Soda taxes and the prices of sodas and other drinks: Evidence from Mexico," *American Journal of Agricultural Economics*, vol. 99, no. 2, p. 481, 2017. [Online]. Available: + http://dx.doi.org/10.1093/ajae/aax024

[21] L. D. Silver, S. W. Ng, S. Ryan-Ibarra, L. S. Taillie, M. Induni, D. R. Miles, J. M. Poti, and B. M. Popkin, "Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, U.S.: A before-and-after study," *PLoS medicine*, vol. 14, no. 4, p. e1002283, 2017.

[22] M. A. Cochero, J. Rivera-Dommarco, B. M. Popkin, and S. W. Ng, "In mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax," *Health Affairs*, pp. 10–1377, 2017.

[23] New York Statewide Coalition of Hispanic Chambers of Commerce v. New York City Department of Health and Mental Hygiene, 16 N.E. 3d 538, N.Y. 2014.

[24] H. Yan, "No Soda Ban Here: Mississippi passes 'Anti-Bloomberg' Bill, CNN, Atlanta, GA, March 21," http://www.cnn.com/2013/03/21/us/mississippi-anti-bloomberg-bill/, 2013.

[25] R. Dobbs, C. Sawers, F. Thompson, J. Manyika, J. R. Woetzel, P. Child, S. McKenna, and A. Spatharou, *Overcoming obesity: An initial economic analysis.* McKinsey Global Institute, 2014.

[26] C. Ogden, B. Kit, M. Carroll, and S. Park, "Consumption of sugar drinks in the United States, 2005–2008. NCHS data brief, no 71. Hyattsville, MD: National Center for Health Statistics. 2011," *US Department of Agriculture, Agricultural Research Service, National Agricultural Library. National nutrient database for standard reference, release*, vol. 25, 2011.

[27] B. Bourquard and S. Y. Wu, "An Economic Analysis of Beverage Size Restrictions." *Purdue University, mimeo*, 2016.

[28] B. M. Wilson, S. Stolarz-Fantino, and E. Fantino, "Regulating the way to obesity: unintended consequences of limiting sugary drink sizes," *PloS one*, vol. 8, no. 4, p. e61081, 2013.

[29] L. K. John, G. E. Donnelly, and C. A. Roberto, "Psychologically informed implementations of sugary-drink portion limits," *Psychological science*, vol. 28, no. 5, pp. 620–629, 2017.

[30] C. Bonnet and V. Réquillart, "Tax incidence with strategic firms in the soft drink market," *Journal of Public Economics*, vol. 106, pp. 77–88, 2013.

[31] J. M. Fletcher, D. E. Frisvold, and N. Tefft, "The effects of soft drink taxes on child and adolescent consumption and weight outcomes," *Journal of Public Economics*, vol. 94, no. 11, pp. 967–974, 2010.

[32] R. B. Myerson, "Incentive compatibility and the bargaining problem," *Econometrica: journal of the Econometric Society*, pp. 61–73, 1979.

[33] D. M. Cutler, E. L. Glaeser, and J. M. Shapiro, "Why have americans become more obese?" *The Journal of Economic Perspectives*, vol. 17, no. 3, pp. 93–118, 2003.

[34] J. A. Harris and F. G. Benedict, "A biometric study of human basal metabolism," *Proceedings of the National Academy of Sciences*, vol. 4, no. 12, pp. 370–373, 1918.

[35] A. M. Roza and H. M. Shizgal, "The harris benedict equation reevaluated: resting energy requirements and the body cell mass." *The American Journal of Clinical Nutrition*, vol. 40, no. 1, pp. 168–182, 1984.

[36] C. C. Douglas, J. C. Lawrence, N. C. Bush, R. A. Oster, B. A. Gower, and B. E. Darnell, "Ability of the harris-benedict formula to predict energy requirements differs with weight history and ethnicity," *Nutrition Research*, vol. 27, no. 4, pp. 194–199, 2007.

[37] S. McGuire, "US department of agriculture and US department of health and human services, dietary guidelines for americans, 2010. Washington, DC: US government printing office, January 2011," 2011.

[38] B. J. Rolls, L. S. Roe, and J. S. Meengs, "Larger portion sizes lead to a sustained increase in energy intake over 2 days," *Journal of the American Dietetic Association*, vol. 106, no. 4, pp. 543–549, 2006.

[39] J. H. Ledikwe, J. A. Ello-Martin, and B. J. Rolls, "Portion sizes and the obesity epidemic," *The Journal of nutrition*, vol. 135, no. 4, pp. 905–909, 2005.

[40] J. E. Flood, L. S. Roe, and B. J. Rolls, "The effect of increased beverage portion size on energy intake at a meal," *Journal of the American Dietetic Association*, vol. 106, no. 12, pp. 1984–1990, 2006.

[41] M. M. Grynbaum, "Soda Makers Begin Their Push Against New York Ban - The New York Times," July 1 2012, retrieved from http://www.nytimes.com.

[42] M. M. Grynbaum and M. Connelly, "60 in City Oppose Bloomberg's Soda Ban, Poll Finds," July 1 2012, retrieved from http://www.nytimes.com.

[43] R. B. Wilson, *Nonlinear pricing*. Oxford University Press on Demand, 1993.

[44] E. Maskin and J. Riley, "Monopoly with incomplete information," *The RAND Journal of Economics*, vol. 15, no. 2, pp. 171–196, 1984.

[45] M. Mussa and S. Rosen, "Monopoly and product quality," *Journal of Economic theory*, vol. 18, no. 2, pp. 301–317, 1978.

[46] B. Bourquard and S. Y. Wu, "An Economic Analysis of Beverage Size Restrictions." *Purdue University, working paper*, 2016.

[47] J. V. Balagtas, J. G. Nuno-Ledesma, and S. Y. Wu, "Portion Restrictions versus Taxes for Regulation of Sugar-Sweetened Beverages," *Purdue University, working paper*, 2017.

[48] J. M. Fletcher, D. Frisvold, and N. Tefft, "Can soft drink taxes reduce population weight?" *Contemporary Economic Policy*, vol. 28, no. 1, pp. 23–35, 2010.

[49] J. M. Fletcher, D. E. Frisvold, and N. Tefft, "Non-linear effects of soda taxes on consumption and weight outcomes," *Health economics*, vol. 24, no. 5, pp. 566–582, 2015.

[50] R. Sturm, L. M. Powell, J. F. Chriqui, and F. J. Chaloupka, "Soda taxes, soft drink consumption, and children's body mass index," *Health Affairs*, pp. 10–1377, 2010.

[51] D. Besanko, S. Donnenfeld, and L. J. White, "The multiproduct firm, quality choice, and regulation," *The Journal of Industrial Economics*, pp. 411–429, 1988.

[52] K. S. Corts, "Regulation of a multi-product monopolist: Effects on pricing and bundling," *The Journal of Industrial Economics*, pp. 377–397, 1995.

[53] B. Greiner, "Subject pool recruitment procedures: organizing experiments with orsee," *Journal of the Economic Science Association*, vol. 1, no. 1, pp. 114–125, 2015.

[54] D. L. Chen, M. Schonger, and C. Wickens, "oTree - An open-source platform for laboratory, online, and field experiments," *Journal of Behavioral and Experimental Finance*, vol. 9, pp. 88–97, 2016.

[55] E. Fehr and K. M. Schmidt, "A theory of fairness, competition, and cooperation," *The Quarterly Journal of Economics*, vol. 114, no. 3, pp. 817–868, 1999.

[56] E. Hoffman, K. McCabe, K. Shachat, and V. Smith, "Preferences, property rights, and anonymity in bargaining games," *Games and Economic behavior*, vol. 7, no. 3, pp. 346–380, 1994.

[57] W. Güth, R. Schmittberger, and B. Schwarze, "An experimental analysis of ultimatum bargaining," *Journal of economic behavior & organization*, vol. 3, no. 4, pp. 367–388, 1982.

[58] E. I. Hoppe and P. W. Schmitz, "Do sellers offer menus of contracts to separate buyer types? An experimental test of adverse selection theory," *Games and Economic Behavior*, vol. 89, pp. 17–33, 2015.

[59] S. Kansagra, "Maximum size for sugary drinks: Proposed amendment of article 81," *New York: Bureau of Chronic Disease Prevention and Tobacco Control: New York Department of Health and Mental Hygiene*, 2012.

[60] Z. Wang, "Supermarkets and gasoline: An empirical study of bundled discounts," *Resources For the Future - Discussion Paper 15-44*, 2015.

[61] W. J. Adams and J. L. Yellen, "Commodity bundling and the burden of monopoly," *The Quarterly Journal of Economics*, pp. 475–498, 1976.

[62] M. Armstrong, "Price discrimination by a many-product firm," *The Review of Economic Studies*, vol. 66, no. 1, pp. 151–168, 1999.

[63] R. P. McAfee, J. McMillan, and M. D. Whinston, "Multiproduct monopoly, commodity bundling, and correlation of values," *The Quarterly Journal of Economics*, vol. 104, no. 2, pp. 371–383, 1989.

[64] G. Carroll, "Robustness and separation in multidimensional screening," *Econometrica*, vol. 85, no. 2, pp. 453–488, 2017.

[65] R. Venkatesh and V. Mahajan, "The design and pricing of bundles: a review of normative guidelines and practical approaches," *Handbook of pricing research in marketing*, vol. 232, 2009.

[66] M. Armstrong and J.-C. Rochet, "Multi-dimensional screening: A user's guide," *European Economic Review*, vol. 43, no. 4-6, pp. 959–979, 1999.

[67] M. Amrstong, S. Cowan, and J. Vickers, "Nonlinear pricing and price cap regulation," *Journal of Public Economics*, vol. 58, no. 1, pp. 33–55, 1995.

[68] A. Caliskan, D. Porter, S. Rassenti, V. L. Smith, and B. J. Wilson, "Exclusionary bundling and the effects of a competitive fringe," *Journal of Institutional and Theoretical Economics JITE*, vol. 163, no. 1, pp. 109–132, 2007.

[69] J. Hinloopen, W. Müller, and H.-T. Normann, "Output commitment through product bundling: Experimental evidence," *European Economic Review*, vol. 65, pp. 164–180, 2014.

APPENDICES

A. APPENDIX: CHARACTERIZATION OF SINGLE-PACKAGE STRATEGIES FOR CHAPTER 2

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.

$$\text{Baseline-pooling-quantity} \begin{cases} \theta_L u'(q^{*2}) = c \end{cases} \tag{A.1}$$

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:

$$\text{Baseline-exclusive-quantity} \begin{cases} \theta_H u'(q^{*3}) = c \end{cases} \tag{A.2}$$

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

$$\text{Cap-pooling-quantity} \begin{cases} p^{**2} = \theta_L u(q^{**2}) \\ \theta_L u'(q^{**2}) = c \end{cases} \tag{A.3}$$

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

$$\text{Cap-pooling-quantity} \begin{cases} \theta_H u'(\hat{q}) = c \end{cases} \tag{A.4}$$

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

$$\text{Tax-pooling-quantity} \begin{cases} \theta_L u'(q^{***2}) = t_s c \end{cases} \tag{A.5}$$

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

$$\text{Tax-exclusive-quantity} \left\{ \theta_H u'(q^{***3}) = t_s c \right. \tag{A.6}$$

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

B. APPENDIX: INSTRUCTIONS FOR THE CAP TREATMENT IN CHAPTER 4

Experimental Instructions

This experiment is about how people sell goods. A clear understanding of the instructions will help you make better decisions and increase your chances of earning more money that will be paid to you in cash at the end of the experiment. During the experiment, you will earn points. **Points will convert to cash at the end of the experiment at the rate of 100.00 points = 1.00 US Dollar**. You are entitled to a $5.00 USD participation fee which will be paid to you in cash at the end of the experiment.

It is important that you don't talk or look at other people's work. If you have any questions, or need any assistance of any kind, please raise your hand. All written information is for your private use only. **Do not pass over any information to other participants**. During the experimental session **you are not allowed to talk, laugh or exclaim out loud**. Be sure to **keep your eyes on your screen only**. Please, **turn off your electronic devices (such as phones, tablets, etc.)** and put them away during the experiment. **Violations of these rules may force us to stop the experiment**. Anybody that violates any of these rules will be asked to leave the laboratory and **will not be paid**. We appreciate your cooperation.

Agenda

1. First, we will go over the instructions.

2. Next, there will be a quiz with 9 questions to make sure that everybody understands the experimental instructions. **You can earn money for each question that you answer correctly.**

    - All 9 questions will be displayed on your computer's screen.

    - You will be asked to answer all of them and then proceed to the next page. You will have only one chance to answer the questions.

    - You earn 25 points for each correct answer. So you can earn up to 225 points if you answer all the questions correctly.

    - Answers for each question will be displayed in the page following the quiz. You should briefly study the questions you got wrong because it might help improve your performance during the experiment.

3. After the quiz, the experiment will begin. The experiment is about how people sell goods.

    - First, there will be a set of non-paying trading periods that will allow you to trade without incurring financial risk.

    - Next, there will be a set of paying trading periods. Your performance in these periods will determine your final earnings.

    - Finally, you will be asked to answer a post-experimental survey.

Description of the Experiment

A Brief Overview

In this experiment every subject in the room is assigned to the role of a seller. You **will not** interact with any other human subject participating in the experiment. You will only interact with a computerized buyer.

To make a trade, a seller will specify a price for a certain size package of an abstract good. The computer will receive your offer and decide whether to buy or not. The price and size of the package agreed upon will determine how much money you make. Trades will occur within a **trading period**. There will be many trading periods throughout the course of this experiment so you will make many trades.

In general, the seller's cost of producing the good is increasing in size. The buyer's payoff is also increasing in size. Moreover, the seller's payoff will be increasing in the price while the buyer's payoff will be decreasing in price. *In short, the buyer benefits from large size at low prices while the seller benefits from high prices at low production cost.*

Also, there are two types of buyers in the marketplace. The **high valuation** type buyer values the good highly. The **low valuation** type buyer still values the good but not as much as the high valuation type does. The seller will not know for certain what type of buyer he/she is trading with.

Specific Trading Instructions

All trades will occur via the computer. Each period is divided into the following phases:

1. **Pricing/packaging phase**. You will observe a screen that allows you to determine the price and size of the package to offer to the computerized buyer.

- Menu choice: You will be asked to choose whether to offer one package, two packages, or not to offer any package for the period. Note: if two-packages are offered, then the buyer will choose **one** of the packages. Thus, you are offering the buyer a "menu" of choices.

- Size - Price choice: After selecting the number of packages to offer, you will be asked to set price and size for each of the packages. The size can be any integer number between 0 and 17. The price can be any integer number between 0 and 25000 points. If you decided not to offer a package for the period, this sub-phase will be skipped.

2. **Purchase phase**. If the seller decides to offer at least one package, the computer will be presented with the price and size of each option and **it will choose the option that maximizes its payoff. The buyer will also reject any package that results in the buyer making a negative payoff**. The computerized buyer has the following alternatives:

   - If offered a single package: Either accept or reject reject the package.

   - If offered a menu of two packages: Either accept package 1, accept package 2, or reject both. The buyer cannot purchase both packages. **If both packages offer the buyer the same positive payoff, then the buyer will randomly select one of the packages.**

At the end of the period, the points you earned will be displayed on the screen. Both the earnings for the period as well as the accumulated earnings from all previous paying periods will be displayed.

You should also document your performance in the paysheet provided to keep track of your past strategies and performance.

Additional Important Information

How many trading periods will there be? The experiment will be divided into two halves:

1. **First half**: There will be 6 **non-paying training periods**. This part provides 6 trading opportunities for you to become familiar with the trading screens and to develop strategies without financial consequences. You should still document your performance on the paysheet to help you learn to improve your strategies.

2. **Second half**: The second half begins following the non-paying periods. There will be 12 paying periods. All periods after the first 6 non-paying periods are **paying periods**. Thus, the points that you earn will be converted into cash at the end of the experiment.

The decisions you make do not affect in any form the decisions or results of other participants in the room. You will be a seller throughout all of the non-paying and paying trading periods.

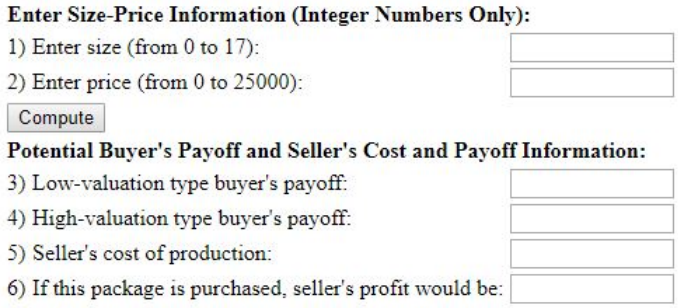
How is the buyer type assigned to the computer? Whether the buyer is a high or a low valuation type in each period will be randomly determined. There is an equal 50-50 chance that the buyer will be a high or low type in each period (similar to a coin-flip). *You will not know for certain what type of buyer you are trading with. You will only know that the computer takes on the role of a high valuation or a low valuation type with 50% probability each.* The computer will behave like a buyer who knows his/her own type. Note: buyer types are not fixed across periods.

How are payoffs calculated?

In each period, if you decide not to make an offer or if the computer rejects your offer, then you earn 0 points for that period.

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

Figure: On-screen Calculator



If you are curious as to how payoffs are affected by size and price, keep in mind the following: *In general, seller payoffs are increasing in price and decreasing in size. This is because it costs more to produce a larger size. Buyer payoffs are increasing in size and decreasing in price.* Also, the buyer would earn zero points if no offer is made or the offer is rejected.

Additionally, for a given package size, High-type buyers will have higher payoffs than Low-type buyers.

For those of you interested in even more details of the equations behind the calculator, below are the equations:

$$\text{High-Type Buyer's payoff} = 300size^{0.95} - price \tag{B.1}$$

$$\text{Low-Type Buyer's payoff} = 290size^{0.95} - price \tag{B.2}$$

Note from the above that the high-type buyer has a much higher valuation ($300size^{0.95}$ versus $290size^{0.95}$)

$$\text{Seller's payoff} = price - 240 \times size \tag{B.3}$$

Notice that "Cost" is determined by the last term $240 \times size$. This means that the larger the size, the larger the cost. If the payoff contains decimals, the computer will round it to the nearest integer.

Initial point balances

During the paying periods, you can make decisions that can earn more points or cause a loss of points.

C. APPENDIX: INSTRUCTIONS FOR THE CAP TREATMENT IN CHAPTER 4

Experimental Instructions

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

Agenda

1. We will go over the instructions.

2. There will be a quiz with 10 questions to make sure everybody understands the experimental instructions. **You will earn 0.20 USD for each question you answer correctly.** All questions will be displayed on your computer's screen. You will have one chance to answer the questions. The correct answers will be

displayed in the page following the quiz. Studying the questions you got wrong might help improve your performance during the experiment.

3. After the quiz, you will be working with a fictitious currency called Points. **Points will convert to cash at the end of the experiment at the rate of 31 points = 1 US Dollar**. The next section of the experiment is divided in two parts:

    - First, there will be a set of training trading periods that will allow you to practice without incurring financial risk.
    - Next, there will be a set of effective trading periods. Your performance in these periods will determine your final earnings.

4. You will be asked to answer a post-experimental survey.

Description of the Experiment

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

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

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

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

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

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

How is the buyer type assigned?

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

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

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

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

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

    - *Menu choice*: You will be asked to decide whether to offer one, two, three or four packages. You can also choose not to offer any package at all.

    - *Quantity - Price choice*: For each package you decided to offer, you will need to specify: 1) quantity of product A, 2) quantity of product B, and 3) the price you would like to charge for the package. The quantity of product A can be any integer number between 0 and 75. The quantity of product B can be any integer number between 0 and 250. The price of the package can be any integer number between 0 and 500. If you decide

not to offer a package for the period, this step will be skipped. This is an image of the interface used to input the quantities and the price for a package.

- 

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

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

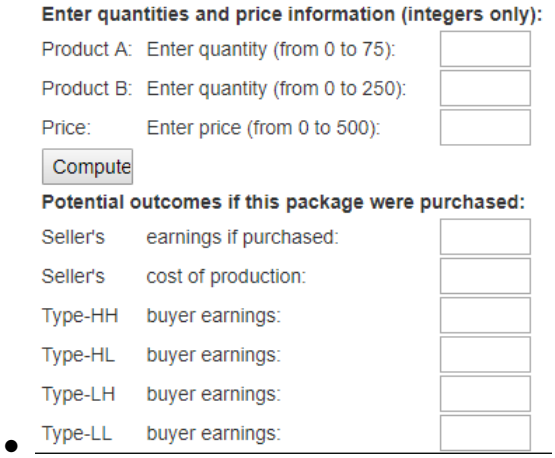
   The buyer compares packages with respect to the earnings he would obtain from buying them. **The buyer will choose the package that yields the**

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

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

How are earnings calculated?

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



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

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

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

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

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

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

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

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

How many trading periods will there be?

The trading part of the experiment will be divided in two parts:

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

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

How do the paying effective periods get selected?

Labeled from 1 to 330, the experimenter has a list with all possible combinations of four effective periods. These are listed with no particular order. On the laboratory's projection screen, you can see a computer interface that randomly chooses numbers between 1 and 330, all equally likely. The experimenter will activate this interface three times. The number that appears the third time will indicate the label of the combination of paying effective trading periods. This label will be displayed on the projection screen during the entire session. On the list, the experimenter will mark

the combination associated with the selected label. He will put the list into a yellow envelope, close the envelope, and leave it on the desk below the projection screen. **Only the experimenter is allowed to open the envelope**. The set of paying effective periods will remain secret until the end of the experiment. Only at the end of the experiment, right before you are paid, the experimenter will privately show you the list of all combinations and the selected combination. Then, the experimenter will proceed to sum the earnings obtained in the randomly selected periods in order to determine your final payoff. If the sum of the four randomly selected effective periods is negative, your trading earnings will be set to zero.