MULTI-PRODUCT NONLINEAR PRICING WITH QUANTITY CAPS

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October 2019

Abstract

I study the effects of limiting the quantity of one product in a two-goods market featuring adverse selection. Following a relatively severe cap, a standard nonlinear pricing model predicts reductions in consumption of the regulated good, and mixed outcomes in consumption of the unregulated good and consumer surplus. Data from an experiment show that all buyers lower their consumption of the regulated good; no significant changes in purchases of the unregulated product occur, and the buyers with low preference for the regulated good and high valuation for the unregulated product are better off, and no buyer type is worse off. That is, both theory and experiment show that some buyers may be better off with a quantity cap. These results have implications for food policy design in settings where protecting consumer surplus is of primary concern.

PRELIMINARY VERSION. PLEASE, DO NOT CITE.

Keywords: nonlinear pricing; quantity cap; adverse selection; multiple products; experiment

JEL classification: C9; D82, I18

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I present theoretical and experimental analyses of the effects of quantity caps (caps) on allocation and consumer surplus in a two-product market with privately-informed buyers. Caps are policies restricting the default maximum quantities at which products can be offered. In light of studies linking larger portion sizes to increased consumption, foods judged to have deleterious impacts on human health are natural targets of potential caps (Young and Nestle (2002), Ledikwe et al. (2005), Rolls et al. (2006), and Flood et al. (2006)). One example of such measures is the so-called "New York City soda ban". The advanced plan intended to prohibit food vendors regulated by the city of New York from selling sugar-sweetened beverages (SSBs) in containers exceeding 16 ounces (Kansagra, 2012).[1] This proposal was struck down in court (New York Statewide Coalition of Hispanic Chambers of Commerce v. New York City Department of Health and Mental Hygiene, 2014). Nevertheless, discussions about possible implementations of caps in the food retail industry are ongoing and contentious.

The main question is: how do consumer surplus and consumption of the goods change following a cap? Opponents argue that consumers' economic well-being are infringed by these interventions. Some of them state that caps could disproportionately impact buyers that prefer to purchase larger quantities of SSBs (Grynbaum (2012); Grynbaum and Connelly (2012)). The implication is that caps result in lower consumer welfare. This assumption is already shaping public policy.Mississippi's Bill 2687 (2013) interdicts against future restrictions of food sales within the state based upon the product's nutrition information or upon its bundling with other items. I argue that because sellers implement sophisticated pricing and bundling policies, even if a regulation modifies consumption of the target product, it does not necessarily follow that consumers are worse-off.

I refer to the goods in the market as A and B. Without regulation, a standard model predicts that the seller offers “small-small”, “medium-large”, “large-medium”, and “large-large” A-B combos. Supposing that A is subject to a cap, limiting any option for A to be strictly lower than the “medium” unregulated size. I aim to learn i) whether the intervention reduces consumption of A, ii) what is the impact on the purchased sizes of the *unregulated* product B, and iii) what is the effect on consumer surplus defined as the gross utility from consumption net of the price paid. I concentrate on studying the seller’s pricing behavior because changes in consumer surplus and allocation patterns are ultimately contingent on how the pricing scheme changes following a regulation. My analysis has two parts: first, I generate hypotheses from a nonlinear pricing model; second, I use data from a laboratory experiment to test them.

This research is important and timely. Obesity rates in the United States hover over 30% (Ogden et al., 2014) and I expect campaigns against consumption of foods associated with obesity to intensify. 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, scant literature on the economic consequences of quantity limits in all industries including food retail. I address this relative gap and look at the case of multi-product markets.

The design of incentive-compatible menus of choices by sellers aiming to segment demand is a well documented phenomenon. The single-product case has received more attention than the multidimensional scenario, see Myerson (1979), Maskin and Riley (1984), Mussa and Rosen (1978), Armstrong and Vickers (1993), and Sonderegger (2011). Perhaps because multidimensional nonlinear pricing is notorious for being a source of research problems easy to state but difficult to solve analytically or otherwise, the literature on the topic has remained relatively small. However, the body of knowledge on multi-product screening continuous to grow and remains a promising field of study. Knowledge in this area has experienced an impressive expansion from its relatively modest beginnings studying highly stylized instances, and the necessary conditions for screening and bundling to be profitable (Adams and Yellen (1976), McAfee et al. (1989), Armstrong (1999)) to the finding of general results (e.g. (Carroll, 2017)), albeit in most cases theoretical results remain highly sensitive to assumptions regarding the choice of key parameters. For discussions about of the literature on design of multi-product pricing and bundling and its evolution, I direct the reader to Venkatesh and Mahajan (2009), Armstrong (1996), and Armstrong (2016).

The advancement in the field has provided researchers with a valuable toolkit to study the effects of regulating price-discriminating firms. In a theoretical study, Besanko et al. (1988) explore the effects of three regulatory measures intending to fix the quantity distortion characteristic of nonlinear pricing:[2] 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, although minimum quality standards do not modify the quantity consumed by the buyers with high valuation for the goods. Corts (1995) analytically studies the effect of imposing a price-cap on the lower level of quantity offered by a multi-product monopolist. Corts relies on a multidimensional version of the Spence-Mirrlees single crossing condition to analyze the multidimensional problem with a one-dimensional screening model. He finds mixed results regarding prices paid by different buyer types. In a numerical example where the multi-item single-crossing assumption is relaxed, Corts show how socially sub-optimal un-bundling may arise as consequence of the intervention. Amrstong et al. (1995) consider two forms of regulations: a cap on the seller's average revenue, and a constraint that forces the seller to keep offering the option to buy a component at the uniform price. Armstrong and co-authors show that the average revenue constraint is preferred by the seller.

The study of quantity caps in multi-product markets is conspicuously absent from the literature. The case of quantity limits in a single-product market is studied by Bourquard and Wu (2019). This article analytically studies the impacts of cap rules with single-product sellers trading with privately-informed heterogeneous buyers. The authors 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. My intention is to investigate the degree to which this finding holds in a more general case.

The study of questions involving multi-commodity settings with experimental data is more common that the theoretical literature related to my topic. Caliskan et al. (2007) and Hinloopen et al. (2014) are largely concerned with evaluating outcomes from the leverage theory of product bundling. In this article, 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: multi-dimensional screening. One experimental article evaluating screening theory is Hoppe and Schmitz (2015), which tests the canonical adverse selection model wherein a seller makes a contract to try to separate a privately informed buyer who has preferences over a low and a high quality item.

More directly related to the topic of regulating food vendors, Wilson et al. (2013) conduct a 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 cap rule. This study is useful because it provides an insight regarding potential framing effects that could alter subjects' purchase decisions. My study complements this work in two dimensions. First, I concentrate 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. Second, my experiment ties monetary rewards to subjects' performance. I reward subjects for taking actions that would make the hypothetical market player they are playing for better off.

I incorporate three stylized observations. First, buyers have private information regarding preferences and these are taken as exogenous by the seller. It is fair to assume that 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 vendors whose pricing strategies include bundling. 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. In the experiment, I allow for flexible contract design. 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.

In the next section, I formally introduce the theoretical model and derive the theoretical hypotheses; in the third part of the document, I present the experimental design; in section four, I present the laboratory data and discuss the experimental results; the last section concludes.

1 Theory

The model is largely based on Armstrong and Rochet (1999), although simplified to facilitate experimental implementation and retain ease of interpretation. I present the characterization of the optimal price schedule before and after the cap. Following succinct discussions of the optimal solutions, I introduce the parameter constellation I use during the experiment.

1.1 Model

The seller (she) 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 products A and B, respectively. The ij-type buyer (he) has private preferences i for good A, and j for B. For each item, buyers can have either high (H) or low (L) preference. There are four types of buyers denoted HH, HL, LH, and LL. The ij-type buyer is characterized by the vector of taste parameters (θ_i^A, θ_j^B) for i, j = H, L. I assume $\theta_H^A = \theta_H^B \equiv \theta_H$, $\theta_L^A = \theta_L^B \equiv \theta_L$, and $\theta_H > \theta_L$. If the ij-type pays price p_{ij} for a package containing quantities q_{ij}^A and q_{ij}^B, he earns consumer surplus:

$$R_{ij} = \theta_i u(q_{ij}^A) + \theta_j u(q_{ij}^B) - p_{ij} \tag{1}$$

The subscripts i and j under R, q^A, q^B, and p indicate the type of consumer. I assume away interactions between the components. In addition to ease experimental implementation, this assumption highlights the interactions between the multidimensional incentive constraints and the seller's pricing behavior across policy scenarios. The no-interaction between components assumption provides a neutral background where changes across treatments can be confidently attributed to the impact of quantity restrictions on pricing behavior without the confounding effects of complementarity. Thus, in this article I will show that a cap changes allocation and consumer surplus *even in the absence of interactions*. Additionally, 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.

I assume the utility function $u(\cdot)$ to be continuous, also $u(0) = 0$, $u'(q) > 0$ and $u''(q) < 0$. The seller and the buyers have reservation values of zero. I assume both goods to have the same differentiable, increasing and convex cost function $c(\cdot)$. Also, $\theta_H u'(q) > c'(q)$ and $\lim_{q\to\infty}\theta_H u'(q) < c'(q)$, so that trade is possible at least with the HH-type, and total quantity supplied is finite. $\sum_{ij} \beta_{ij} = 1$, so β_{ij} represents the probability that a given buyer is of an

ij-type. Lastly, let $\beta_{HL} = \beta_{LH} = \beta$ so that instances HL and LH are equally likely. The seller's expected profit is $\mathbb{E}[\pi] = \sum_{ij} \beta_{ij} \Big[p_{ij} - c(q^A_{ij}) - c(q^B_{ij}) \Big]$. It is useful to represent expected profit in terms of total and consumer surpluses:

$$\mathbb{E}[\pi] = \underbrace{\sum_{ij} \beta_{ij}[\theta_i u(q^A_{ij}) + \theta_j u(q^B_{ij}) - c(q^A_{ij}) - c(q^B_{ij})]}_{\text{Expected total surplus}} - \underbrace{\sum_{ij} \beta_{ij}[\theta_i u(q^A_{ij}) + \theta_j u(q^B_{ij}) - p_{ij}]}_{\text{Expected consumer surplus}} \tag{2}$$

The seller considers one set of participation constraints (PC), and another of incentive-compatibility restrictions (IC). Satisfaction of PC implies that all types are at least indifferent between buying and opting out from trade. Their general form is PC: $R_{ij} \geq 0 \ \forall \ ij$.

The IC restrictions are self-selection conditions providing incentives for the ij-type not to purchase a package originally intended to serve a kl-type buyer ($i \neq k$, and $j \neq l$). In other words, at the optimum, quantities and prices are such that the ij-type buyer is weakly better-off by choosing contract $\{q^A_{ij}, q^B_{ij}, p_{ij}\}$ over an alternative $\{q^A_{kl}, q^B_{kl}, p_{kl}\}$. The seller designs a menu of contracts such that the ij-type receives positive surplus in the form of a temptation payoff known as information rents. These are exactly equal to the extraordinary benefit the ij-type would have gained had he chosen the contract intended for the kl-type from a menu with linear prices. The IC constraints take the following form:

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

The complete optimization program includes 8 PC and 12 IC restrictions. The seller's goal is to design options $\{q_{ij}^A, q_{ij}^B, p_{ij}\}$ to maximize expected profit (2) subject to the PC and IC constraints just described. The resulting pricing mechanism is incentive-compatible if it satisfies monotonicity conditions: $q_{HH}^A \geq q_{LH}^A$, $q_{HL}^A \geq q_{LL}^A$, $q_{HH}^B \geq q_{HL}^B$, and $q_{LH}^B \geq q_{LL}^B$. These state that the quantity of either good is weakly increasing with the corresponding valuation.

In a "relaxed" version of the problem, only a subset of the constraints are included. The seller ignores the possibility of lower types misrepresenting their preferences. As long as the PC restriction for the LL-type is satisfied, the seller does not have to worry of the LL-type purchasing any other package but the smallest; therefore, only the lowest participation constraint is relevant. Additionally, only the "downward" incentive restrictions are incorporated.[3] In the appendix, I show that the solution to the simplified problem is the solution to the fully constrained program. The relevant IC constraints are graphically depicted in panel A in Figure 1, where solid lines stand for equations binding with equality, and dashed lines indicate restrictions that may or may not bind with strict equality depending on the problem's parameters (especially the distribution of types) and the seller's pricing strategy.

[Figure 1 about here.]

The specific form of R_{HH} will produce a particular *Incentive Compatibility Structure* (IC Structure). R_{HH} can take four forms: 1) IC Structure A: $R_{HH} = \Delta[u(q_{LL}^A) + u(q_{LL}^B)] + \Delta[u(q_{LH}^A) - u(q_{LL}^A)] + \Delta[u(q_{HL}^B) - u(q_{LL}^B)]$; 2) IC Structure B: $R_{HH} = \Delta[u(q_{LL}^A) + u(q_{LL}^B)] + \Delta[u(q_{LH}^A) - u(q_{LL}^A)]$; 3) IC Structure C: $R_{HH} = \Delta[u(q_{LL}^A) + u(q_{LL}^B)] + \Delta[u(q_{HL}^B) - u(q_{LL}^B)]$, and 4) IC Structure D: $R_{HH} = \Delta[u(q_{LL}^A) + u(q_{LL}^B)]$. Where $\Delta \equiv \theta_H - \theta_L$.

Taking into consideration the forms of the incentive restriction for the HH-type is important because in each IC Structure, different sets of IC constraints bind with equality, implying solutions with different allocations and consumer surplus distribution. For economy of space, I develop my discussion around IC Structure A in the main text of the article. In the appendix, I present a complete characterization of allocation and consumer surplus distribution without and with regulation for all IC Structures. Naturally, the effects of a quantity limit on allocation and consumer rents are contingent on the IC structure characterizing the market without regulation. Before continuing with an explanation about what this implies for the consequences of limiting the quantity of one the goods, I dedicate a few paragraphs to the phenomenon of commodity bundling.

1.2 Commodity Bundling

In this document, the seller practices pure bundling. The products are said to be bundled if the variance in price across different packages is not entirely explained by differences in marginal cost of production. Particularly, if at the solution the quantity of product i increases with the preference for good j, the menu of options is said to feature bundling 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 $q^B_{LH} < q^B_{HH}$.

The assumption of pure bundling comes with advantages. First, it reduces the complexity of the multidimensional pricing model and facilitates interpretation. Easiness of interpretation is a scarce attribute in models of multidimensional screening, and every opportunity to facilitate the understanding of outcomes is highly valuable. Second, it simplifies experimental implementation and makes it easy for subjects to understand their task. Lastly, the assumption can help to illuminate the effects of caps on pricing practices in products we typically do not think of as bundles. For example, consider a soda manufacturer deciding sugar-water (possible A-B products) combinations.[4] The "package" is a bottle of soda with a particular sugar-water ratio. Applying it to this scenario, the baseline outcomes that I present later can be interpreted as follows: 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 cap would be a restriction in the maximum quantity of sugar allowed in a bottle of soda. [5]

The decision to bundle is highly sensitive to the distribution of buyer types. A given distribution of types is conducive to bundling when the correlation of preferences, $\rho = \beta_{HH}\beta_{LL} - \beta^2$, is weak enough (Armstrong and Rochet (1999), McAfee et al. (1989), and Adams and Yellen (1976)). Bundling is profitable as long as $\rho < \frac{\beta^2}{\beta_{LL}}$. I present results for the case when $\rho < 0 < \frac{\beta^2}{\beta_{LL}}$; this is when the incentive to bundle is the strongest. I take this decision for two reasons. First, in the food retail industry commodity bundling is rampant. Second, the pricing strategy followed by a multi-product vendor that does not bundle is identical to single-product nonlinear pricing applied separately to each good.

1.3 Baseline and quantity-restricted cases

Without regulation, the price-discriminating seller offers A and B in combos containing "small", "medium", and "large" portions of each. Panel A in Figure 2 is a helpful illustration of the resulting allocation. Consumer rents increase with preferences, with the LL-type earning no rents, the HH-type gaining the largest surplus, and the medium HL and LH-types earning the same rents, as illustrated in panel B of Figure 3.[6] In general, 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.

[Figure 2 and 3 about here]

Without loss of generality, suppose that the quantity limit applies to A, and options of A can not be larger than $\bar{q}$. The seller's objective is to maximize 2 subject to participation and incentive-compatibility constraints, plus the following quantity cap (QC) restriction:

$$\text{QC:} \;\; q_{ij}^{A} \leq \bar{q} \;\text{ for } i,\, j = L,\, H \tag{4}$$

There are three levels of severity at which the cap can be set. The limit can be 1) mild if the limit is set below the "large" 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 "small" regulation-free alternative, or 3) harsh if the limit on quantity is set at a level lower than the "small" alternative without the cap.

I present the First Order Conditions and the impacts on quantities and consumer surplus for each level of cap severity and for all four IC structures in the appendix, but I discuss them briefly here. A mild cap does not modify the set of binding constraints, and the seller offers as much of A as she is allowed for the HH and HL types. The moderate and harsh limits do modify the set of binding IC constraints. Panel B in Figure 1 represents them.

The constraint involving the LH type possibly posing as an HL type binds with equality for all cases when, in the original IC Structure, the IC constraint involving the the HH and HL-types were binding with equality (IC Structures A, C, and D). This can be confirmed using equation 3. As the quantity of product A becomes smaller due to more restrictive caps, the seller has to be mindful 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. For IC Structure B, where without intervention the HH to HL IC constraint does not bind with equality, it is possible for some parameter constellations that the imposition of moderate and harsh restrictions do not automatically cause the LH to HL IC constraint to bind. For purposes of this article and its appendix, I use the roman numeral I to refer to the cases in which the moderate and harsh levels of restriction cause the LH to HL IC constraint to bind, and use the numeral II to denote the cases when these levels of severity do cause this IC equation to bind.

Consider the case of a moderate restriction in IC Structure A. The moderate restriction approximates the design of the cap rule proposed in 2012 in New York City. The regulated outcomes on quantities and consumer rents are illustrated in panels B of figures 2 and 3. The model predicts that a severe enough cap on A will reduce consumption of A; increase consumption of B by the LL buyer; decrease consumption of B by the HL type; increase consumer surplus for the LH-type, and reduce consumer rents for the HH-type.

The moderate cap results in bunching of HH and LH-type buyers which purchase the same option. 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 interactions between the two products are absent, it is surprising to find that the model suggests changes for the quantity of the *unregulated* product B purchased by the HL and LL-type buyers. According to the theoretical outcomes, the HL-type buyer is offered less of product B, whereas the LL receives *more* of it. Once the cap is implemented, her desire to price-discriminate continues and the restriction merely reduces her choice space. To accommodate the policy while continuing to segment the demand, 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. In essence, these are driven by the LL-type's participation constraint and the need to provide positive rents to the LH-type to purchase his own package. Without regulation, information rents for the LH-type are driven by a larger quantity of 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 good 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.

I now turn to discuss the modifications in the package sold to the HL-buyer. These are explained by 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 A to the HL-type buyer. Indeed 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 B compared to the LL package. Because the quantity of 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 B granted to the HL-type consumer to generate information rents need not be as large. This explains the reduction in consumption of B from the HL-type buyer.

Regarding the impacts on buyers' surplus, the model predicts 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 A for which he has a low preference. 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, whereas the "large-large" package is just too expensive for this buyer. A quantity limit 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.

1.4 Hypotheses

Before discussing the experimental design, I list the set of hypotheses to evaluate following a moderate quantity cap on good A.

Hypothesis *1.* *Consumption of A.* All buyer types reduce their consumption of the regulated product A.

Hypothesis *2.* *Consumption of 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 B.

Hypothesis *3.* *Expected profit and consumer rents.* 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.

In table 1, I show the parameters I use in the experiment. 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. The line in figure 4 highlights "symmetric" combination of probabilities where $\beta_{HH} = \beta_{LL}$ and the incentive to bundle is the strongest. The combination of probabilities I chose lies relatively far from "border" and corner regions in the 2-simplex. Moreover, because 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 simplifies the experimental instructions.

[Table 1 and Figure 4 here]

2 Experimental design

In total, 82 subjects were randomly assigned to one of two experimental treatments: *Baseline* or *Cap* named after their policy environment. There were three sessions per treatment with 12 to 14 subjects each. Sessions were conducted between October and November of 2017. Payoff functions and the ranges of choice variables given to the subjects can be seen in table 2. Subjects were recruited via ORSEE (Greiner, 2015). The experimental interface was designed with oTree (Chen et al., 2016). No subject participated in more than one session.

[Table 2 about here]

In all sessions, subjects play “trading periods” in which the seller submits a menu of choices and the buyer makes consumption decisions. There are 6 training periods with no financial consequences to familiarize subjects with the interface and game structure. Following the training phase, each subject plays 11 paying effective 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. A computer program mimics the choices of a rational consumer whose type was randomly and independently assigned before each trading period. Throughout the experiment, earnings are denominated in points. Final earnings are converted into cash at the exchange rate was 31 points per US Dollar following protocol I describe below. 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.

The game in each trading period closely mirrors the screening problem I described in the previous sections. At the beginning of each trading round, the seller chooses to offer a number of packages from one to four, or 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 A, quantity of 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. They can take notes in a paper earning tracking sheet provided by the experimenter. Subjects also have access to a calculator during the menu-design phase of the trading periods. With this calculator, they 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 subjects. 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 is activated before the experiment started. The application was activated three time. The number that appeared the third time represented the label of the selected combination of paying periods. The selected paying combination was shown to each subject after they finished with all of their tasks. If the sum earnings of the four randomly selected periods was negative, the earnings of the subject was set to zero. This protocol was detailed in the experimental instructions.

3 Experimental results

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

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 5. Remember that two goods are said to be bundled if the quantity of product j increases with preference for component i. This is graphically confirmed in figure 5, assuming that the smaller, and second smaller packages target LL and LH types, and 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 5 to be sufficient evidence of sellers attempting to bundle.

[Figure 5 about here]

I now turn to the way in which the characteristics of the menus evolved across periods. 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 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 document. In table 3 I show average price and quantities of the packages purchased by each buyer type in both treatments. In both treatments, price and quantities are larger in later periods.

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. Table 4 shows 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.

[Tables 3 and 4 about here]

3.1 Main experimental results

For all menus of contracts that subjects submitted during the trading periods, I compute 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.

I start by looking at the impacts on quantity purchased by type of buyer. In table 5, I show econometric estimates of the 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.

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

***Main Result** 2. In accordance with hypothesis 2, the cap rule does not impact the quantity of product B purchased by the HH and LH-type buyers. In opposition to hypothesis 2, 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.*

Under regulation, 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 significant change in purchases of product B by any type.

I turn to the distributional impacts of the cap shown in table 6. The main hypotheses are that the LH-type is better off after the cap, although the HH-type is worse off.

Main Result *3. In opposition to hypothesis 3: 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 3 the LH-type buyer earns a larger surplus. The HL and LL-type's surpluses remain unchanged.*

As predicted, the LH-type is better off after the cap. 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, the HH-type buyer is not impacted by the cap. The main reason can be found in table 7. The HH-buyer is buying less of A which 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.

[Tables 5, 6 and 7 about here]

To put the empirical results in perspective, it is useful to compare them with the model's predictions. 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 5, I do observe a statistically significant reduction in quantity of 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, these changes in the mix of quantities consumed by the LL-type result in a null impact on his consumer rents (table 6). Because the price paid by this buyer type remained unaffected across treatments, as can be seen in table 7, the LL-type's rents are held constant.

Recall that the model predicts the HL-type would reduce his consumption of both products when the cap is enacted. The empirical estimates in table 5 suggest that this buyer does reduce his consumption of A (q^A_{HL}), but does not modify his consumption of B (q^B_{HL}). The model predicts a null impact on the information rents earned by this buyer and this what I find in the data (see table 6). 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.

The notable result of an increased surplus earned by the LH-type buyer following a cap is corroborated by the experimental data. Looking at the estimates in tables 5 and 6, I conclude that the increase in surplus is explained by the reduction in the quantity of A acquired by this buyer (the product for which this buyer has a low valuation): the cap moves the choice set closer to this buyer's first best.

The model generated the following hypotheses regarding the HH-type consumer: 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 5). Surprisingly, however, there is not a significant reduction in the surplus earned by this customer. This is because, during the experiment, this buyer paid lower prices (see table 7) and the reduction is large enough to keep his rents constant.

4 Conclusion

According to a standard nonlinear pricing model, a cap 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 HL-type buyer; iv) larger consumer surplus for the LH-type buyer, v) lower consumer rents for the HH-type buyer, and vi) no change in consumer surplus for the other buyers. The experimental evidence suggests that a moderate quantity cap would be successful at reducing consumption of the targeted product for 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. 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.

The assumption that quantity caps negatively impact consumer well-being is an important driver of public discourse surrounding food policy and at it is already shaping public policy. I show that these worries are not justified. A cap can increase consumer well-being for some buyers. The benefited buyers have low valuation for the regulated product but high preference for the unregulated goods. Absent a quantity limit, 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 (in the form of larger sizes of the lowly-preferred product) can be leveraged as a sorting device .

Future work ought to expand the model and experiment with complementarity between the components. Additionally, formal comparisons between the impacts of quantity limits and other popular measures such as excise taxes seem to be natural extensions.

Notes

[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.

[2]Price-discriminating firms distort quantity downward along the type space.

[3]The seller does not consider the possibility of the HL-type choosing the packages intended for either the LH-type or the LL-types and, similarly, she does not have to worry about the LH-type buyer choosing the option designed to serve the HL and/or the HH-type.

[4]In this example, the reader can interpret A as "sugar", and B as "all other ingredients" .

[5]To illustrate how bundling appears in this article, consider a hypothetical menu where the options serving the LL and HL-types contain quantities $(q^A_{LL},\ q^B_{LL}) = (5,\ 5)$, and $(q^A_{HL},\ q^B_{HL}) = (15,\ 10)$. The difference between the quantities of A allocated to buyers LL and HL can be well explained by the difference in preferences between these two types. The amounts of B served to these same buyers cannot be explained by an increase in predilection of B, because both buyers have the same low preference for it. The HL-buyer is offered a larger amount of B (so B is bundled with A) so that he is not tempted to purchase the package designed for the LL-type.

[6]I omit scale labels along the vertical axis of both figures because the specific values of these variables depend on the chosen parameters. For some parameter combinations, 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.

Tables and figures

Table 1: Parameter values used in this study

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

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

Table 2: Experimental treatments

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

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

	Baseline				Cap			
	LL	LH	HL	HH	LL	LH	HL	HH
All periods:								
Mean price	160.14	209.66	211.35	218.80	128.97	180.04	170.19	184.22
Mean q^A	93.27	98.32	117.15	115.87	48.71	48.57	56.59	55.32
Mean q^B	90.58	112.93	97.11	107.98	95.21	120.12	97.03	117.19
First 5 periods:								
Mean price	145.49	197.63	200.18	204.39	121.30	171.55	162.18	177.25
Mean q^A	84.82	92.07	112.38	108.53	37.50	45.76	54.05	52.97
Mean q^B	83.80	107.98	91.26	101.30	88.67	114.05	92.13	112.22
Last 6 periods:								
Mean price	173.66	219.69	220.75	230.57	136.26	187.14	176.79	190.03
Mean q^A	101.06	103.53	121.16	121.87	45.16	51.19	57.28	57.28
Mean q^B	96.83	117.05	102.03	113.45	101.43	125.19	101.07	121.33

Table 4: Average per-period earnings

	Number of observed packages (Baseline)				Number of observed packages (Cap)			
	0	1	2	3	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)	2/462 (0.4)	300/462 (64.9)	121/462 (26.2)	39/462 (8.4)
Mean R_{LL}	0	10.96	8.51	8.01	0	15.69	9.85	5.10
Mean R_{LH}	0	40.25	33.81	36.51	0	52.18	36.68	34.75
Mean R_{HL}	0	41.48	34.04	36.60	0	35.29	27.93	25.47
Mean R_{HH}	0	90.44	79.59	74.73	0	87.13	72.34	62.26
Mean payoff seller	0	142.33	144.51	140.93	0	126.00	135.33	134.41
Mean $\mathbb{E}[\pi]$	0	107.15	110.39	117.62	0	95.93	102.04	117.38
First 5 periods:								
#Obs/Total (Share)	4/200 (2.0)	111/200 (55.5)	76/200 (38.0)	9/200 (4.5)	1/210 (0.5)	133/210 (63.3)	58/210 (27.6)	18/210 (8.6)
Mean R_{LL}	0	16.70	8.10	8.95	0	17.75	12.17	3.24
Mean R_{LH}	0	48.44	33.76	39.25	0	53.60	41.71	34.66
Mean R_{HL}	0	49.52	33.53	39.84	0	36.50	33.22	25.02
Mean R_{HH}	0	96.49	78.13	77.96	0	87.31	76.13	62.23
Mean payoff seller	0	136.68	142.38	134.61	0	117.70	127.62	144.21
Mean $\mathbb{E}[\pi]$	0	102.34	109.46	121.51	0	92.17	105.36	120.87
Last 6 periods:								
#Obs/Total (Share)	0/240 (0.0)	140/240 (58.3)	94/240 (39.1)	6/240 (2.5)	1/252 (0.4)	167/252 (66.3)	63/252 (25.0)	21/252 (8.3)
Mean R_{LL}	0	6.41	8.84	6.61	0	14.05	7.71	6.70
Mean R_{LH}	0	33.76	33.85	32.40	0	51.05	32.04	34.83
Mean R_{HL}	0	35.10	34.45	31.74	0	34.32	23.05	25.85
Mean R_{HH}	0	85.65	80.77	69.88	0	86.99	68.85	62.29
Mean payoff seller	0	146.81	146.23	150.41	0	132.61	142.43	126.01
Mean $\mathbb{E}[\pi]$	0	110.96	111.14	111.78	0	98.92	99.00	114.39

Table 5: Estimates: impact of the quantity cap on per-period quantities purchased per buyer type

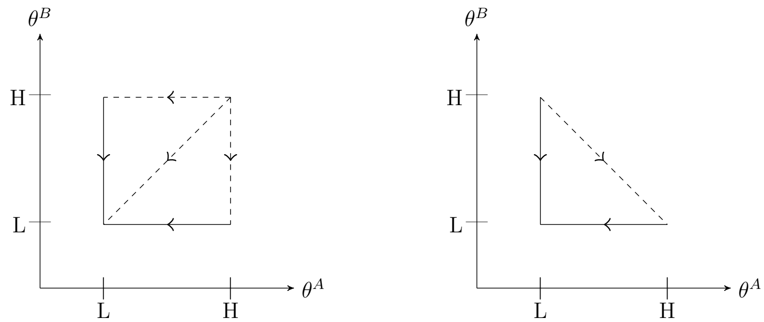
	q^A_{HH}	q^B_{HH}	q^A_{HL}	q^B_{HL}	q^A_{LH}	q^B_{LH}	q^A_{LL}	q^B_{LL}
Cap dummy	-60.065***	9.504	-61.061***	0.609	-49.066***	7.587	-44.567***	9.480
	(8.635)	(11.694)	(9.803)	(9.616)	(8.761)	(12.153)	(5.779)	(9.374)
Period	1.593***	1.647***	1.269***	1.670***	1.512***	1.485***	1.940***	1.984***
	(0.341)	(0.494)	(0.228)	(0.355)	(0.464)	(0.427)	(0.444)	(0.656)
Constant	105.752***	97.726***	109.174***	86.587***	88.623***	103.507***	71.523***	70.542***
	(7.841)	(6.929)	(8.510)	(6.474)	(5.725)	(10.393)	(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.

Table 6: 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	-8.975	-13.382	-4.109	-5.683	9.151**	3.388
	(8.765)	(12.179)	(3.903)	(4.946)	(4.227)	(3.548)
Period	0.992**	2.108***	-0.509	-0.966***	-1.071***	-0.796***
	(0.387)	(0.358)	(0.406)	(0.357)	(0.344)	(0.214)
Constant	101.952***	129.345***	87.950***	43.866***	43.703***	14.592***
	(8.437)	(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.



(A) Baseline

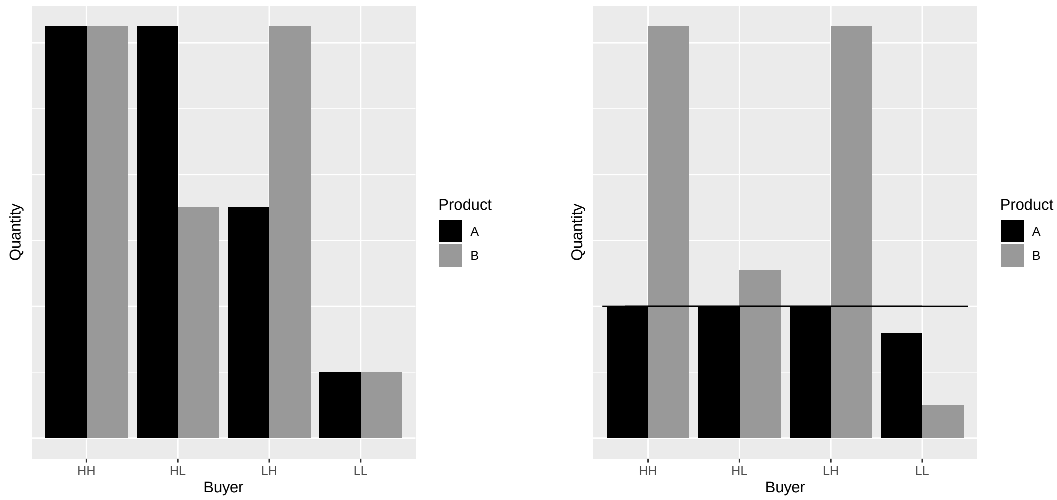
(B) Quantity cap

Figure 1: IC constraints in the relaxed problem

Table 7: Estimates: impact of the quantity cap on per-period prices

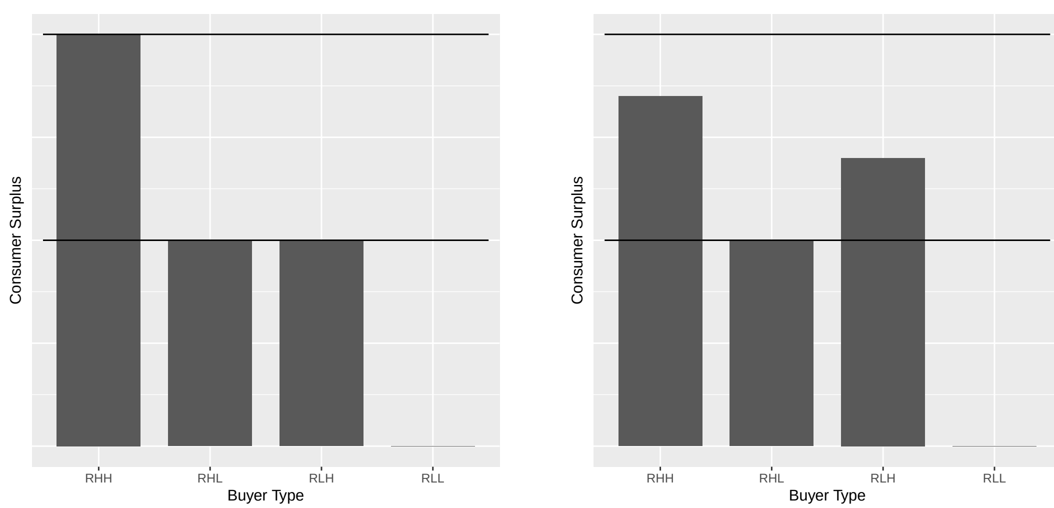
	p_{HH}	p_{HL}	p_{LH}	p_{LL}
Cap dummy	-34.163*	-41.644**	-28.745	-18.345
	(19.122)	(19.860)	(18.661)	(15.219)
Period	3.355***	3.200***	3.180***	3.596***
	(0.680)	(0.524)	(0.568)	(0.792)
Constant	198.185***	191.572***	189.616***	118.163***
	(16.693)	(16.872)	(16.421)	(13.467)
Observations	896	872	890	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.



(A) Baseline (B) Quantity cap

Figure 2: Allocation by types (Theory)



(A) Baseline (B) Quantity cap

Figure 3: Consumer surplus by types (Theory)

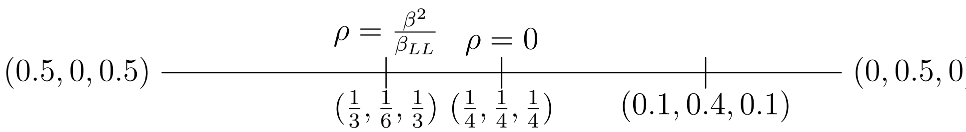


Figure 4: Probabilities of buyer types (β_{HH}, β, β_{LL})

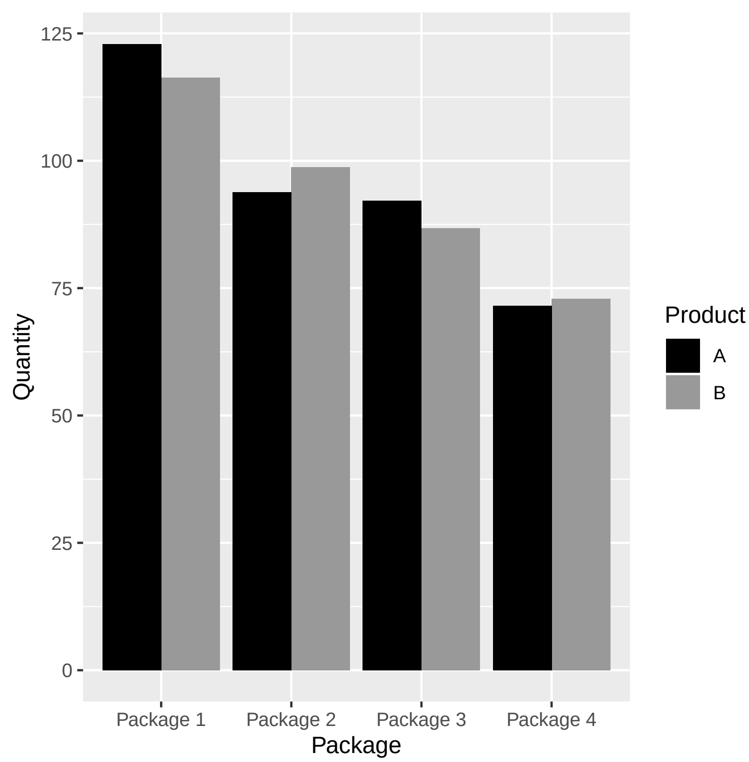


Figure 5: Packages by sum of offered quantities: Baseline

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Appendix

The solution to the relaxed problem is the solution to the fully constrained program. I show this is the case for IC-Structure A. The proofs for the other IC Structures are very similar. I solve the profit maximization problem. The seller maximizes expected profit (2) subject to the following restrictions:

$$R_{LL} = 0$$

$$R_{LH} = u(q^B_{LL})\Delta$$

$$R_{HL} = u(q^A_{LL})\Delta$$

$$R_{HH} = \Delta[u(q^A_{LL}) + u(q^B_{LL})] + \Delta[u(q^A_{LH}) - u(q^A_{LL})] + \Delta[u(q^B_{HL}) - u(q^B_{LL})]$$

$$q^A_{HH} \geq q^A_{LH},\ q^A_{HL} \geq q^A_{LL},\ q^B_{HH} \geq q^B_{HL}, q^B_{LH} \geq q^B_{LL}$$

Where: $\Delta \equiv \theta_H - \theta_L$

The solution implies the following outcomes:

- Quantities:
  - Goods A and B are served in a "small" portions. $q^*_{LL} \equiv q^{A*}_{LL} = q^{B*}_{LL}$.
  - There is a "medium" portion. $q^*_{LH} \equiv q^{A*}_{LH} = q^{B*}_{HL}$.
  - There are "large" portions. $q^*_{HL} \equiv q^{A*}_{HL} = q^{B*}_{LH}$ and $q_{HH*} \equiv q^{A*}_{HH} = q^{A*}_{HH}$.
  - The quantities consumed by the LL, LH, HL and HH, respectively are: (q^*_{LL}, q^*_{LL}), (q^*_{LH}, q^*_{HL}), (q^*_{HL}, q^*_{LH}), and (q^*_{HH}, q^*_{HH}).
- Consumer Surplus:

– $R^*_{LL} = 0$.

– $R^*_{LH} = \Delta u(q^*_{LL})$.

– $R^*_{HL} = \Delta u(q^*_{LL})$.

– $R^*_{HH} = 2\Delta u(q^*_{LH})$.

***Proposition** 1.* *I closely follow the proofs in Armstrong and Rochet (1999). Maximizing 2 subject to 4 gives the solution to the seller's fully constrained problem.*

Proof. Proposition 1. *Together, $R_{LL} = 0$, the monotonicity constraints, plus the four binding constraints in panel A in Figure 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 corresponfing first order conditions, 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:

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

□

Table 8: IC Structure A - First Order Conditions Across Regulations and Associated Quantity Changes

LHS FOC:	$\theta_H u'(q^A_{HH})$	$\theta_H u'(q^B_{HH})$	$\theta_H u'(q^A_{HL})$	$\theta_L u'(q^B_{HL})$	$\theta_L u'(q^A_{LH})$	$\theta_H u'(q^B_{LH})$	$\theta_L u'(q^A_{LL})$	$\theta_L u'(q^B_{LL})$
RHS FOC:								
Baseline	$c'(q^A_{HH})$	$c'(q^B_{HH})$	$c'(q^A_{HL})$	$\frac{c'(q^B_{HL})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^A_{LH})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Mild	$c'(\bar{q})$	$c'(q^B_{HH})$	$c'(\bar{q})$	$\frac{c'(q^B_{HL})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^A_{LH})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Moderate - II	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$c'(q^B_{HH})$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$\frac{c'(q^B_{HL})}{1-\frac{\Delta}{\theta_L}}$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{(\beta_H+\beta)\frac{\theta_H}{\theta_L}+\beta(1-\frac{\Delta}{\theta_L})}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-2\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$
Harsh - II	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$c'(q^B_{HH})$	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$\frac{c'(q^B_{HL})}{1+\frac{\Delta}{\theta_L}}$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$c'(q^B_{LH})$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$\frac{c'(q^B_{LL})}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$
	q^A_{HH}	q^B_{HH}	q^A_{HL}	q^B_{HL}	q^A_{LH}	q^B_{LH}	q^A_{LL}	q^B_{LL}
Quantities:								
Baseline	-	-	-	-	-	-	-	-
Mild	$\downarrow$	=	$\downarrow$	=	=	=	=	=
Moderate- II	$\downarrow$	=	$\downarrow$	$\downarrow$	$\downarrow$	=	$\downarrow$	$\uparrow$
Harsh - II	$\downarrow$	=	$\downarrow$	$\downarrow$	$\downarrow$	=	$\downarrow$	$\uparrow$

The rows called LHS FOC and RHS FOC present, correspondingly, the left hand side and the right hand side of the First Order Conditions under the corresponding policy scenarios. The direction of the impact on quantities is obtained by comparing the corresponding intervention scenario with the unregulated baseline.

Table 9: IC Structure B - First Order Conditions Across Regulations and Associated Quantity Changes

LHS FOC:	$\theta_H u'(q^A_{HH})$	$\theta_H u'(q^B_{HH})$	$\theta_H u'(q^A_{HL})$	$\theta_L u'(q^B_{HL})$	$\theta_L u'(q^A_{LH})$	$\theta_H u'(q^B_{LH})$	$\theta_L u'(q^A_{LL})$	$\theta_L u'(q^B_{LL})$
RHS FOC:								
Baseline	$c'(q^A_{HH})$	$c'(q^B_{HH})$	$c'(q^A_{HL})$	$c'(q^B_{HL})$	$\frac{c'(q^A_{LH})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Mild	$c'(\bar{q})$	$c'(q^B_{HH})$	$c'(\bar{q})$	$c'(q^B_{HL})$	$\frac{c'(q^A_{LH})}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Moderate - I	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L}{\theta_H}\right)}$	$c'(q^B_{HH})$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L}{\theta_H}\right)}$	$c'(q^B_{HL})$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}\frac{\theta_H}{\theta_L}+\beta(1+\frac{\theta_H}{\theta_L})}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Moderate - II	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$c'(q^B_{HH})$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$\frac{c'(q^B_{HL})}{1-\frac{\Delta}{\theta_L}}$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{(\beta_H+\beta)\frac{\theta_H}{\theta_L}+\beta(1-\frac{\Delta}{\theta_L})}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-2\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$
Harsh - I	$\frac{c'(\bar{q})}{\frac{\theta_L}{\theta_H}(2\beta+\beta_L)+\beta_H}$	$c'(q^B_{HH})$	$\frac{c'(\bar{q})}{\frac{\theta_L}{\theta_H}(2\beta+\beta_L)+\beta_H}$	$c'(q^B_{HL})$	$\frac{c'(\bar{q})}{\frac{\theta_H}{\theta_L}\beta_H+2\beta+\beta LL}$	$c'(q^B_{LH})$	$\frac{c'(\bar{q})}{\frac{\theta_H}{\theta_L}\beta_H+2\beta+\beta LL}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Harsh - II	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$c'(q^B_{HH})$	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$\frac{c'(q^B_{HL})}{1+\frac{\Delta}{\theta_L}}$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$c'(q^B_{LH})$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$\frac{c'(q^B_{LL})}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$
	q^A_{HH}	q^B_{HH}	q^A_{HL}	q^B_{HL}	q^A_{LH}	q^B_{LH}	q^A_{LL}	q^B_{LL}
Quantities:								
Baseline	-	-	-	-	-	-	-	-
Mild	$\downarrow$	=	$\downarrow$	=	=	=	=	=
Moderate - I	$\downarrow$	=	$\downarrow$	=	$\downarrow$	=	=	$\uparrow$
Moderate - II	$\downarrow$	=	$\downarrow$	$\downarrow$	$\downarrow$	=	$\downarrow$	$\uparrow^*$
Harsh - I	$\downarrow$	=	$\downarrow$	=	$\downarrow$	=	$\downarrow$	$\uparrow$
Harsh - II	$\downarrow$	=	$\downarrow$	$\downarrow$	$\downarrow$	=	$\downarrow$	$\uparrow^*$

The rows called LHS FOC and RHS FOC present, correspondingly, the left hand side and the right hand side of the First Order Conditions under the corresponding policy scenarios. The direction of the impact on quantities is obtained by comparing the corresponding intervention scenario with the unregulated baseline.

$*$ The effect is $\uparrow$ if $\beta > \frac{\beta_H+\beta}{\beta_{LL}}$, but $\downarrow$ if $\beta < \frac{\beta_H+\beta}{\beta_{LL}}$.

Table 10: IC Structure C - First Order Conditions Across Regulations and Associated Quantity Changes

LHS FOC:	$\theta_H u'(q_{HH}^A)$	$\theta_H u'(q_{HH}^B)$	$\theta_H u'(q_{HL}^A)$	$\theta_L u'(q_{HL}^B)$	$\theta_L u'(q_{LH}^A)$	$\theta_H u'(q_{LH}^B)$	$\theta_L u'(q_{LL}^A)$	$\theta_L u'(q_{LL}^B)$
RHS FOC:								
Baseline	$c'(q_{HH}^A)$	$c'(q_{HH}^B)$	$c'(q_{HL}^A)$	$\frac{c'(q_{HL}^B)}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$c'(q_{LH}^A)$	$c'(q_{LH}^B)$	$\frac{c'(q_{LL}^A)}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q_{LL}^B)}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Mild	$c'(\bar{q})$	$c'(q_{HH}^B)$	$c'(q_{HL}^A)$	$\frac{c'(q_{HL}^B)}{\left(1-\frac{\beta_{HH}}{\beta}\frac{\Delta}{\theta_L}\right)}$	$c'(q_{LH}^A)$	$c'(q_{LH}^B)$	$\frac{c'(q_{LL}^A)}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q_{LL}^B)}{\left(1-\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Moderate - II	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$c'(q_{HH}^B)$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$\frac{c'(q_{HL}^B)}{1-\frac{\Delta}{\theta_L}}$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{(\beta_H+\beta)\frac{\theta_H}{\theta_L}+\beta(1-\frac{\Delta}{\theta_L})}$	$c'(q_{LH}^B)$	$\frac{c'(q_{LL}^A)}{\left(1-2\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q_{LL}^B)}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$
Harsh - II	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$c'(q_{HH}^B)$	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$\frac{c'(q_{HL}^B)}{1+\frac{\Delta}{\theta_L}}$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$c'(q_{LH}^B)$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$\frac{c'(q_{LL}^B)}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$

	q_{HH}^A	q_{HH}^B	q_{HL}^A	q_{HL}^B	q_{LH}^A	q_{LH}^B	q_{LL}^A	q_{LL}^B
Quantities:								
Baseline	-	-	-	-	-	-	-	-
Mild	$\downarrow$	$=$	$\downarrow$	$=$	$=$	$=$	$=$	$=$
Moderate - II	$\downarrow$	$=$	$\downarrow$	$\uparrow$	$\downarrow$	$=$	$\uparrow^*$	$\uparrow$
Harsh - II	$\downarrow$	$=$	$\downarrow$	$\uparrow$	$\downarrow$	$=$	$\downarrow$	$\uparrow$

The rows called LHS FOC and RHS FOC present, correspondingly, the left hand side and the right hand side of the First Order Conditions under the corresponding policy scenarios. The direction of the impact on quantities is obtained by comparing the corresponding intervention scenario with the unregulated baseline.
$*$ The effect is $\uparrow$ if $\beta < \beta_H$, but $\downarrow$ if $\beta > \beta_H$.

Table 11: IC Structure D - First Order Conditions Across Regulations and Associated Quantity Changes

LHS FOC:	$\theta_H u'(q^A_{HH})$	$\theta_H u'(q^B_{HH})$	$\theta_H u'(q^A_{HL})$	$\theta_L u'(q^B_{HL})$	$\theta_L u'(q^A_{LH})$	$\theta_H u'(q^B_{LH})$	$\theta_L u'(q^A_{LL})$	$\theta_L u'(q^B_{LL})$
RHS FOC:								
Baseline	$c'(q^A_{HH})$	$c'(q^B_{HH})$	$c'(q^A_{HL})$	$c'(q^B_{HL})$	$c'(q^A_{LH})$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Mild	$c'(\bar{q})$	$c'(q^B_{HH})$	$c'(q^A_{HL})$	$c'(q^B_{HL})$	$c'(q^A_{LH})$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\frac{\beta_{HH}+\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$
Moderate - II	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$c'(q^B_{HH})$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{\beta_{HH}+2\beta\frac{\theta_L}{\theta_H}}$	$\frac{c'(q^B_{HL})}{1-\frac{\Delta}{\theta_L}}$	$\frac{(\beta_{HH}+2\beta)c'(\bar{q})}{(\beta_H+\beta)\frac{\theta_H}{\theta_L}+\beta(1-\frac{\Delta}{\theta_L})}$	$c'(q^B_{LH})$	$\frac{c'(q^A_{LL})}{\left(1-2\frac{\beta}{\beta_{LL}}\frac{\Delta}{\theta_L}\right)}$	$\frac{c'(q^B_{LL})}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$
Harsh - II	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$c'(q^B_{HH})$	$\frac{c'(\bar{q})}{\beta_{HH}+\beta\left(1+\frac{\theta_L-3\Delta}{\theta_L}\right)+\beta_{LL}\frac{\theta_L}{\theta_H}}$	$\frac{c'(q^B_{HL})}{1+\frac{\Delta}{\theta_L}}$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$c'(q^B_{LH})$	$\frac{c'(\bar{q})}{\beta_H\frac{\theta_H}{\theta_L}+\beta\left(1+\frac{\theta_H-3\Delta}{\theta_L}\right)+\beta_{LL}}$	$\frac{c'(q^B_{LL})}{\left(1-\beta\frac{\Delta}{\theta_L}\right)}$

	q^A_{HH}	q^B_{HH}	q^A_{HL}	q^B_{HL}	q^A_{LH}	q^B_{LH}	q^A_{LL}	q^B_{LL}
Quantities:								
Baseline	-	-	-	-	-	-	-	-
Mild	$\downarrow$	$=$	$\downarrow$	$=$	$=$	$=$	$=$	$=$
Moderate - II	$\downarrow$	$=$	$\downarrow$	$\uparrow$	$\downarrow$	$=$	$\uparrow^{*}$	$\uparrow^{**}$
Harsh - II	$\downarrow$	$=$	$\downarrow$	$\uparrow$	$\downarrow$	$=$	$\downarrow$	$\uparrow^{**}$

The rows called LHS FOC and RHS FOC present, correspondingly, the left hand side and the right hand side of the First Order Conditions under the corresponding policy scenarios. The direction of the impact on quantities is obtained by comparing the corresponding intervention scenario with the unregulated baseline.

$*$ The effect is $\uparrow$ if $\beta < \beta_H$, but $\downarrow$ if $\beta > \beta_H$.

$**$ The effect is $\uparrow$ if $\beta > \frac{\beta_H+\beta}{\beta_{LL}}$, but $\downarrow$ if $\beta < \frac{\beta_H+\beta}{\beta_{LL}}$.

Table 12: IC Structure A - Buyers' Rents Across Regulations

	R_{HH}		R_{HL}		R_{LH}		R_{LL}	
Base	$\Delta[u(q^A_{LH}) + u(q^B_{HL})]$		$\Delta u(q^A_{LL})$		$\Delta u(q^B_{LL})$		0	
Mild	$\Delta[u(q^A_{LH}) + u(q^B_{HL})]$	$(=)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta u(q^B_{LL})$	$(=)$	0	$(=)$
Moderate-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\downarrow^*)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$
Harsh-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\downarrow^*)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$

The direction of the impact on rents is obtained by comparing the corresponding intervention scenario with the unregulated baseline.
$*$ The effect is $\downarrow$ as long as $u(q^A_{LL}) + u(q^B_{LL}) < u(q^A_{LH})$.

Table 13: IC Structure B - Buyers' Rents Across Regulations

	R_{HH}		R_{HL}		R_{LH}		R_{LL}	
Base	$\Delta[u(q^A_{LH}) + u(q^B_{LL})]$		$\Delta u(q^A_{LL})$		$\Delta u(q^B_{LL})$		0	
Mild	$\Delta[u(q^A_{LH}) + u(q^B_{LL})]$	$(=)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta u(q^B_{LL})$	$(=)$	0	$(=)$
Moderate-I	$\Delta[u(\bar{q}) + u(q^B_{LL})]$	$(\downarrow)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta u(q^B_{LL})$	$(=)$	0	$(=)$
Moderate-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\downarrow^*)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$
Harsh-I	$\Delta[u(\bar{q}) + u(q^B_{LL})]$	$(\downarrow)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta u(q^B_{LL})$	$(=)$	0	$(=)$
Harsh-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\downarrow^*)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$

The direction of the impact on rents is obtained by comparing the corresponding intervention scenario with the unregulated baseline.
$*$ The effect is $\downarrow$ as long as $u(q^A_{LL}) + u(q^B_{HL}) < u(q^A_{LH})$.

Table 14: IC Structure C - Buyers' Rents Across Regulations

	R_{HH}		R_{HL}		R_{LH}		R_{LL}	
Base	$\Delta[u(q^A_{LL}) + u(q^B_{HL})]$		$\Delta u(q^A_{LL})$		$\Delta u(q^B_{LL})$		0	
Mild	$\Delta[u(q^A_{LL}) + u(q^B_{HL})]$	$(=)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta u(q^B_{LL})$	$(=)$	0	$(=)$
Moderate-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\uparrow)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$
Harsh-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\uparrow)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$

The direction of the impact on rents is obtained by comparing the corresponding intervention scenario with the unregulated baseline.

Table 15: IC Structure D - Buyers' Rents Across Regulations

	R_{HH}		R_{HL}		R_{LH}		R_{LL}	
Base	$\Delta[u(q^A_{LL}) + u(q^B_{LL})]$		$\Delta u(q^A_{LL})$		$\Delta u(q^B_{LL})$		0	
Mild	$\Delta[u(q^A_{LL}) + u(q^B_{LL})]$	$(=)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta u(q^B_{LL})$	$(=)$	0	$(=)$
Moderate-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\uparrow)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$
Harsh-II	$\Delta[u(q^A_{LL}) + u(q^B_{LL}) + u(q^B_{HL})]$	$(\uparrow)$	$\Delta u(q^A_{LL})$	$(=)$	$\Delta[u(q^B_{LL}) + u(q^A_{LL}) - u(\bar{q}) + u(q^B_{HL})]$	$(\uparrow)$	0	$(=)$

The direction of the impact on rents is obtained by comparing the corresponding intervention scenario with the unregulated baseline.