Taxation and Market Power*

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Abstract

We analyze the incidence and welfare effects of unit sales tax increases in experimental monopoly and Bertrand markets. We find, in line with economic theory, that firms with no market power are able to shift a high share of the tax burden on to consumers, independent of whether buyers are automated or human players. In monopoly markets, a monopolist bears a large share of the burden of a tax increase. With human buyers, however, this share is smaller than with automated buyers as the presence of human buyers constrains the pricing behavior of a monopolist. Several control treatments corroborate this finding.

Keywords: tax incidence, monopoly, Bertrand competition, experiment

JEL classification Codes: H22, L12, L13, C72, C92

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1 Introduction

The economic incidence effects of taxation in the context of markets is a core issue in public finance. Who bears the economic burden of a specific tax has implications for policy-makers and for the political economy of taxation. The analysis of the tax-induced economic burden as a function of market conditions and market power has, hence, attracted considerable attention in the theory of taxation.[1] Yet there is a discrepancy between the predictions of standard economic theory and the public opinion on the impact of market power on the burden of a tax (as illustrated below). Moreover, empirical studies of tax incidence in specific markets have led to mixed results. In this paper we provide experimental evidence on the role of market power for the incidence effects and welfare effects of taxation. We compare the incidence effects of a unit sales tax increase for the case of monopoly with the incidence effects for Bertrand competition, allowing for two different regimes regarding consumers' decision making.[2]

Textbook theory suggests that monopoly firms typically bear a large share of the burden of an increase in sales taxes, whereas firms with little or no market power can often shift all of the additional tax burden to the buyers (Myles 1995, 358-363). Intuitively, Bertrand competition between firms without market power should make prices fall to the point of zero profits. Thus, with Bertrand competition for homogenous products, firms cannot bear the burden of an additional tax. If their unit cost of production is increased by a tax, either they can shift the burden of this tax to the buyers, or they must exit the market (Fullerton and Metcalf 2002, 1824). In contrast, monopolists choose monopoly prices in the absence of taxation, maximizing their monopoly profits. If they have to pay a unit tax on sales, the monopoly profit can potentially serve as a buffer that enables them to absorb this cost shock. The monopolist may adjust the price in line with the marginal-cost-equals-marginal-revenue calculation. Depending on the demand and the marginal cost curve, this may cause an increase in the monopoly price by less or more than the amount of the tax, and the cost increase will hurt the monopolist strongly (Bishop 1968).[3]

The incidence of a specific tax has also become the focus of much empirical research. Studies

[1] See Fullerton and Metcalf (2002) for a detailed survey.

[2] The impact of a tax decrease need not be symmetric. Experimental work by Bayer and Ke (2011) addresses a different question and considers different informational assumptions, but highlights the potential for asymmetric implications for the observed transaction price.

[3] Theoretical considerations are less straightforward for imperfect competition with more than one firm. Seade (1985) and Stern (1987) show that firms may shift more than the total increase in their unit costs onwards to customers in different frameworks with imperfect competition. Collusion and its break-down, entry and exit decisions, combined with a non-linear cost structure and specificities of the demand function may play a role. Hamilton (2009) highlights the importance of multiproduct markets.

of specific markets find a large variety of pass-through rates of taxes both for Bertrand competition and for imperfect competition.[4] Moreover, the question of pass-through of cost increases—whether tax induced or not—is a key question for practitioners in capital markets, and the perceptions articulated by practitioners and non-economists are often in contrast with the theory predictions of tax incidence theory. The financial newspaper *Financial Times Deutschland*, citing a UBS research paper, analyzes investment strategies in times of cost inflation. The author of the article argues that investors should seek firms with much market power.[5] Global equity research at UBS by Nelson et al. (2008) recommends the purchase of "price makers" to deal with cost inflation, and a paper about pricing power by Exane BNP Paribas (Exane BNP Paribas 2008, 11) states that they expect firms with "genuine pricing power" to outperform the market in times with cost inflation. They identify three channels for pricing power to help in an environment with increasing cost. One of these is a type of monopoly power (see page 11):

> Brands are used by companies to allow them to charge premium prices. When prices rise, customer loyalty means that there will be a limited impact on demand. Even if a lower-price product is available, especially if the product does not represent a significant proportion of a consumer budget, the brand-loyal customer will pay up. This means that it may be possible to preserve margins in an inflationary environment.

This perception may be contrasted with the theory's point of view: monopolists should have already used an existing range for price increases, rather than wait for a cost shock before using the available opportunities for profit maximization.

The divergence between practitioners' perceptions and theory predictions, and the heterogeneous empirical results together with the multiplicity of different possible factors causing these

[4] Seade (1985) gives as motivation for his theoretical analysis the successful cost-shifting by large multinational oil companies during the first oil crisis. Kim and Cotterill (2008) find pass-through rates of 21-31 percent under collusion and between 73 and 103 percent under Bertrand competition for a market with differentiated brands. Studies by Devereux and Lanot (2003) and Chouinard and Perloff (2004) show a pass-through in the interior between 0 and 100 percent for mortgages and gasoline taxes, respectively. Poterba (1996) considers the markets for clothing, essentially confirming the theoretical predictions about a 100 percent pass-through of taxes in competitive markets. Besley and Rosen (1999) consider prices in different locations which apply different sales taxes and find that, in line with the competitive markets theory, the higher taxes are fully passed through. For some products, however, they find prices that are substantially higher than for a full pass-through. For instance, for alcohol taxes, pass through rates above 100 percent occur more frequently. Young and Bielinska-Kwapisz (2002) find evidence suggesting that excise taxes on alcohol increase the price of alcohol by three times the amount of the excise tax increase. Kenkel (2005) shows that increases in per-unit taxes on alcoholic beverages were more than fully passed through to consumers in Alaska and surveys other studies for several different markets.

[5] Financial Times Deutschland, 24 July 2008, 'Marktmacht hilft in Inflationszeiten', http://www.ftd.de/finanzen/maerkte/:portfolio-marktmacht-hilft-in-inflationszeiten/389704.html (accessed 20 November 2012).

pass-through rates highlight the importance of studying the tax incidence effect of market power in an experimental framework that makes it possible to isolate the effect of market power which pertains to the theoretical considerations. For this purpose we analyze the equilibrium reactions to a unit sales-tax increase both for a monopoly market and for a Bertrand market for homogenous products. We derive theory predictions for the specific market framework and consider which of the theory predictions is in line with the observed behavior in the experiment. In order to be able to distinguish between pure supply-side effects (monopoly versus competition) and the role of strategic interaction between buyers and sellers (automated buyers versus truly human decision-makers) we consider two different demand regimes. For one market regime firms know that they sell their goods to a market with automated demand that emulates customers behaving in line with textbook economics. In this context, sellers do not face any uncertainty about the buyers' reactions to market prices. We find that Bertrand competition in the experimental market is in perfect conformity with textbook economics: Bertrand competitors fully pass through the tax increase to their customers. For the monopoly equilibrium with automated demand, the empirical outcome is also close to the textbook prediction. We then consider the same monopoly and Bertrand setups with buyers who are not automated but real human customers whose purchasing decisions may, but need not necessarily, coincide with the predictions of standard consumer theory. We find that Bertrand competitors who are dealing with (and know they are dealing with) real customers are also successful in passing through their full tax-induced cost increases to the buyers, similar to the results with automated demand. Deviations from the textbook predictions seemingly occur for the monopoly with real human buyers. Monopolists who know they offer their goods to real players do not achieve the monopoly price as an equilibrium outcome even before the tax increase, but their asking prices can be interpreted as a payoff maximizing response to the behavior of buyers. Some buyers refuse to buy if the price is too close to their (laboratory-induced) monetary valuation, and with the demand curve that results endogenously from this, the theory prediction for the monopolist's behavior also becomes different from monopolists who sell to automated buyers. As a result, the increase in the monopolist's cost increases the equilibrium price; however, the increase is less than half the size of the tax-induced increase in the monopolist's cost. This result on monopoly pricing and tax incidence effects in the presence of real human buyers is confirmed in several control treatments. The results of three additional treatments are reported in an independent section. We confirm that the results in case of monopoly with real human buyers is not due to effects of repeated interaction. It is qualitatively robust to monopolists' capacity constraints and independent of the specifics of sequencing where buyers react to posted prices, rather than setting themselves a reservation price before observing the posted price.

Few earlier studies considered taxes in experimental markets[6], and even fewer experiments on tax incidence have been carried out. None of these studies considered the role of market power. Kerschbamer and Kirchsteiger (2000), Kachelmeier et al. (1994), Borck et al. (2002), Riedl and Tyran (2005) and Ruffle (2005) study the relationship between statutory and economic incidence: whether the statutory rule about who physically delivers the tax to the tax authorities affects the incidence of the tax. All of these studies keep the market institution and the nature of demand constant. Quirmbach et al. (1996), addressing the incidence of corporate taxation in a simple Harberger-type general equilibrium game, find that capital owners are able to shift some share of the burden of capital taxation. However, their experiment does not make it possible to address the relationship between market power and tax incidence. In contrast, we study the role of market power for tax shifting and for the size of the excess burden, and how this result depends on whether the demand side consists of real buyers as decision-makers. This fundamental role of market structure for tax incidence and the excess burden of taxation has received surprisingly little attention in experimental work.

We use a simple framework that enables us to make strong and straightforward predictions about tax incidence. This framework is described in section 2. Testable hypotheses about the incidence and welfare properties of the unit sales tax as a function of market structure are developed in section 3. Section 4 describes the experimental design and explains these choices, discussing how our experimental design relates to the experimental markets literature, as our analysis builds upon experience on experimental market games.[7] Section 5 contains the experimental results on tax incidence in Bertrand vs. monopoly markets. Section 6 reports the results of three control treatments for the case of monopoly with real buyers. Finally, Section 7 concludes.

2 Tax incidence with block demand

We consider a market for a single homogeneous good. The good is produced by n firms, where $n = 1$ refers to the monopoly case and $n = 4$ involves competition, and the good is sold to $m = 4$ buyers.

[6] Incentive effects of taxes have been studied in the context of labour leisure choices (see, e.g., Sillamaa 1999, Sutter and Weck-Hannemann 2003, Ortona et al. 2008, Lévy-Garboua et al. 2009). The role of taxes for the performance of markets has also received some attention. Bloomfield et al. (2009) analyze the role of transaction taxes for trade in financial markets with informed and noise traders, and find that they affect both types of traders similarly.

[7] The literature is surveyed, e.g., by Plott (1989) and Holt (1995).

Each firm can produce units of this good for a constant unit cost equal to $c = 6.5$. In addition, for each unit sold, the firm needs to pay a unit sales tax equal to $t \in \{2, 6\}$, causing tax-inclusive total unit cost of production of $c+t$. Each firm i chooses a price $p_i \in \mathbb{N}$. We consider a finite grid of prices that maps the finite grid of prices that exists in real markets, due to currency indivisibilities. It also has the practical benefit of making the pricing equilibrium unique, and avoids open-set problems regarding optimal choice.[8] At price p_i, the firm i is willing to produce and sell as many units as are demanded. A simple price revelation mechanism matches firms and buyers together: the market mechanism identifies the lowest offer price and announces this offer price to the buyers. Buyers observe the lowest offer price and decide whether to purchase one unit of the homogeneous good at this price. A buyer either purchases exactly one unit, or does not buy at all. All buyers forward the units they purchase to the laboratory and receive $q = 24.5$ laboratory currency units per unit of the good. We call this price the (laboratory-induced) monetary valuation. If several firms offer the good at the same lowest price, the number of units demanded is assumed to be allocated evenly among the sellers.

If all sellers and buyers maximize their monetary payoffs, this game has a unique Nash equilibrium for each of the different parameter values $(n, t) \in \{(1, 2), (1, 6), (4, 2), (4, 6)\}$. For $n = 1$ the seller is a monopolist facing a block demand of four units. The profit-maximizing integer price p_1 is 24, yielding a profit that is equal to $\pi_M = 62$ for $t = 2$ and $\pi_M = 46$ for $t = 6$. Consumer rent for each buyer is equal to 0.5 for both values of the unit tax. This market equilibrium is efficient. The tax does not distort the allocation, and it does not generate an excess burden in the market. Further, the higher tax causes an increase in the tax revenue from $TR_{(t=2)} = 8$ to $TR_{(t=6)} = 24$. At the same time, the monopoly profit falls from 62 to 46, a decrease of precisely the same size as the increase in the tax revenue. This determines the tax incidence: the increase in the sales tax is fully borne by the monopolist.

Turning to the cases of Bertrand competition, $(n, t) \in \{(4, 2), (4, 6)\}$, the Nash equilibrium in prices has $p_i = p = 9$ for all $i = 1, 2, 3, 4$ if $t = 2$, and $p_i = p = 13$ if $t = 6$. As a result, each buyer purchases one unit and each firm sells one unit at the equilibrium price. Each seller makes a profit equal to 0.5 for both levels of taxes. Each buyer has a consumer rent of $24.5 - p$, which is equal to 15.5 for $t = 2$ and equal to 11.5 for $t = 6$. Accordingly, for the Bertrand market the loss in the aggregate sum of producer and consumer rents is again equal to the tax revenue from the increased sales tax. Moreover, the tax is fully borne by the buyers. Bertrand competitors can fully

[8] For a discussion of the role of a smallest unit for Bertrand equilibrium see Hehenkamp and Leininger (1999).

shift the burden of taxes onwards to the buyers.

These results illustrate a cornerstone of partial analytic theory of tax incidence: with block demand, a monopolist bears the burden of higher taxes, whereas sellers with no market power can pass this burden through to their customers. The experiments can reveal whether these fundamental results do materialize, and which additional effects are present. One set of treatments compares monopoly and Bertrand competition, isolating supply effects by replacing real demand by automated demand, which makes the demand behavior for different prices fully predictable for suppliers. A second set of treatments adds demand decisions by real individuals. This introduces a potentially important element of strategic uncertainty. Sellers must form expectations about purchase decisions of buyers. Sellers know that buyers are paid 24.5 for each unit of the good that they purchase. However, whether buyers actually buy at a given smallest observed price is another matter. An implicit assumption in the textbook analysis is that buyers purchase if and only if their monetary valuation of the good is higher than the offer price. If real individuals make the purchasing decisions, their actual net benefit from the purchase decision may deviate from the externally induced monetary valuation. Assume, for instance, that buyers consider the monopoly situation similar to an ultimatum game: by suggesting a price, the monopolist offers the buyer a piece of the pie. The buyer then has to accept or refuse this offer. The theory of ultimatum games generated a wealth of evidence for why we should not expect an outcome in which the monopolist charges 24, but a smaller price, and why some buyers may reject prices of 24 or lower. Many of these theories fit well with the idea that buyers are heterogenous in their boycott behavior. Let, for instance, $F(p)$ be the share of buyers who accept all prices lower than or equal to p. The monopolist then simply faces an uncertain demand function, where the size of the demand at a given price is $mF(p)$, where m is the number of units sold.

3 Theoretical predictions

The hypotheses focus on how market power affects the ability of sellers to shift the tax burden onwards to buyers, and whether human decision-making on the buyers' side plays a role. We expect the strategic uncertainty generated by human buyers' decision-making to play a key role. The first conjecture, stated as a testable hypothesis, addresses the case with automated demand:

Hypothesis 1 *In the absence of strategic demand uncertainty (i.e., with automated demand), Bertrand competitors can fully pass on the burden of a tax increase to the buyers. A monopo-*

list cannot pass on the burden of taxation to its buyers. The monopolist bears the full burden of an additional tax.

Human buyers may, but need not purchase a good. They may 'boycott' even if the offer price is below their benefit in monetary terms if they do purchase the good.[9] The strategic problem is closely related to an ultimatum game, with the monopolist as proposer, with the main difference that the proposer makes four simultaneous offers that all need to be identical and which may be accepted or rejected independently, rather than games with one "proposer" and one "responder". The ultimatum game is perhaps the most carefully studied strategic setting in experimental economics.[10] This literature documents well that the proposer offers a substantial amount rather than offering close to nothing and that responders refuse quite substantial amounts offered. The literature also offers a number of explanations,[11] and this paper is not intended to reach the definite answer about the 'why'. However, based on the insights from this literature we expect that many players performing as monopolists do not make minimum offers, and that a considerable share of buyers reject price offers that would yield them a substantial material payoff. We therefore expect buyers to be more likely to boycott if (a) the absolute monetary rent they sacrifice by their refusal to purchase is small, or if (b) the price offer they face gives them a small share in the overall rent that has to be shared between the seller(s) and the buyers. It follows that each buyer may have a threshold price and may purchase if and only if the price is not higher than their respective threshold price. This threshold need not be the same for all buyers. This generates a demand function that might differ from block demand. The hypotheses about the two treatments with real (human) buyers are as follows. Consider first Bertrand competition. In the textbook equilibrium the market price drops to the price closest to the sellers' tax-inclusive costs. A seller's fear of possible boycott cannot reasonably drive down the price further than that. Since the price charged is likely to be below the buyers' threshold price, boycott considerations should therefore not play a role for Bertrand competition. The empirical Bertrand game outcomes for automated and human buyers

[9] Consumer boycotts are a widespread phenomenon in real markets. For instance, Dolliver (2000) reports that 50% of Americans declared to have participated in a product boycott. Motivations to participate in what is called 'economic consumer boycotts' are manifold; among them unethical production or marketing practices or unfair price increases (see, e.g., Friedman 1995, 1999). Also in lab markets, consumer boycotts and demand withholding is reported to be a robust phenomenon (see, e.g. Ruffle 2000, Tyran and Engelmann 2005, or Brown Kruse 2008).

[10] The first, seminal contribution is by Güth et al. (1982). An early survey is Güth and Tietz (1990). A recent survey is by Güth and Kocher (2012). A meta-study is by Oosterbeek et al. (2004). Andersen et al. (2011) study the role of high stakes, focusing also mainly on responder behavior and showing that higher stakes increase the acceptance probability by responders for given share offers.

[11] These include various other-regarding preferences, the proposer's concerns about non-monetary considerations affecting the decision making of the responder, such as self-esteem, or satisfaction from punishment behavior, the use of heuristics that are shaped in situations with repeated interaction, among others.

should not systematically differ. Bertrand competitors should be able to shift the burden of taxes onwards to the buyers also if these are human buyers. For the monopoly case, the boycott option of human buyers can make a difference. The monopolist charges a price close to the buyers' monetary valuation for the case of automated buyers. This compares to offering a minimal amount in the ultimatum game. Accordingly, monopolists may charge a price that splits the surplus similarly to what happens in the ultimatum game. Hence, the tax increase may have an impact on pricing behavior and buying decisions, as it affects the surplus to be shared between seller and buyers. The testable hypothesis on tax incidence effects with real buyers is:

Hypothesis 2 *With demand choices made by real individuals, Bertrand competitors can pass on the entire burden of a tax increase. A monopolist can pass on a significant part of the tax increase to the buyers.*

Moreover, we expect buyer boycott to become an issue in the monopoly case, and the aggregation of individual demand functions should lead to an aggregate demand function that differs from block demand. We will test the following hypothesis on buying decisions in the case of monopoly with real buyers.

Hypothesis 3 *For real buyers in a monopoly market, the observed demand differs from block demand and is downward-sloping for a range of prices that is smaller than the monetary gross benefit from purchasing the good.*

We can use the observed demand decisions in the experiment to estimate this (potentially) downward-sloping demand pattern and ask whether, and to what extent, the monopolist's pricing pattern is a profit-maximizing reply to this demand pattern. Facing a market price offer of p, the buyer must decide whether to purchase a unit or to boycott. If buyers differ in their threshold price used for their buying decision, this generates a cumulative distribution function $F(p)$ describing the share of buyers purchasing a unit of the good for each possible offer price. In a purely static framework, if the monopolist knows the probability distribution $F(p)$ and wishes to maximize his monetary payoff, his expected payoff is equal to

$$(p - c - t)F(p)m,$$

where m is the number of buyers. The strategic multi-period problem is potentially more complicated. The monopolist may have a prior belief about $F(p)$ and may experiment in order to find out about what types of buyers he was matched with. The buyers may, therefore, act strategically when making their choices in early rounds. This latter motivation for each single buyer is absent if the number of buyers is large, because each buyer then considers his own influence on the probability update of the monopolist as insignificant. If each of the the four buyers feels sufficiently small, this eliminates the incentive of strategic purchasing behavior and simplifies the problem.[12] The monopolist can then use the buyers' decisions in the first $N-1$ rounds to find an estimate about $F(p)$ and choose a price in the last round that maximizes the expected profit that emerges from this estimate about $F(p)$. When analyzing behavior in the case of monopoly with real buyers, we will check whether, in later rounds, the monopolist reacts optimally to the observed demand.

Boycott is a possible source of inefficiency: if a purchase does not take place, the value between production cost and the buyers' induced monetary valuation will be lost, and therefore the boycott behavior of real buyers and pricing of firms has implications for surplus and its distribution. If the conjectures about Bertrand competition are correct, then, in a framework with block demand, the imposition of a unit sales tax does not generate a material deadweight loss (defined as the total sacrifice in monetary payoffs of the seller, the buyers and the government compared to transactions that maximize this monetary sum). For the monopoly case, in the absence of strategic buyer uncertainty, the monopolist should earn a material profit equal to $m \times (24 - c - t)$ and the sum of buyers' material payoffs should be equal to $0.5 \times m$ (where m is again the number of buyers). Due to buyers' boycott and monopolists' pricing choices, the monopoly profit is $F(p)m(p - c - t)$, and the monopolist chooses the $p(t)$ maximizing this expression. The average material payoff of a buyer is $F(p)(24.5 - p)$ for this profit-maximizing price. The tax revenue is $tF(p)m$. The material deadweight loss can be described as

$$[1 - F(p(t))]\, m(24.5 - c). \tag{1}$$

Note that, in a world in which aspects other than own material payoff matters to players, material payoff is not an encompassing measure of welfare. 'Welfare' easily becomes an elusive concept—and at least strongly depends on the nature of these other aspects. Nevertheless, it is interesting to ask whether the loss in material surplus in the monopoly case with real buyers increases or decreases if the tax rate is higher. With boycott considerations being absent, both tax

[12] One of the control treatments to be introduced in Section 6 (called "MonReal-Rand") implements monopoly markets in a random-matching design (where such strategic purchasing behavior is impossible) and will hence serve as a robustness check of this assumption.

rates $t \in \{2, 6\}$ should yield an outcome in which four units are sold. With boycott considerations several countervailing effects can be at work. First, if the unit sales tax is increased, this may change the maximum price that a buyer may be willing to accept. One natural conjecture would be that the observed increase in the seller's tax-inclusive unit cost may make a buyer more inclined to accept a given price. As this may be conjectured by the monopolists as well, they may also charge a higher price in this case, leaving it open whether the increase in the tax causes an increase or a decrease in transactions. Second, the increase in the unit tax narrows the range in which possible mutually beneficial transactions can take place from the set of prices $\{9, 10, .., 24\}$ to the set $\{13, 14, ..., 24\}$, which in turn may reduce the boycott problem. To see this, consider the extreme with $t = 17$. For this tax, the set of prices yielding a positive monetary payoff for the monopolist and for the buyers has only one element: $p = 24$. We would expect that, for $t = 17$, buyers do not boycott at a price of $p = 24$. Hence, narrowing down the range of mutually profitable transaction prices may enhance total material payoff.[13]

An important question for the external validity is whether such boycott considerations are important in monopoly markets outside the laboratory. With many buyers, each buyer has a very small impact on the monopolist's payoff. But consumer boycotts occur, and abuse of monopoly power is one of the motivations listed.[14] Where consumer boycotts occur and are motivated by considerations such as abuse of monopoly power, boycott considerations have implications for the demand function which the monopolist faces. In the experiment it converts block demand into a demand function that is gradually downward sloping. As is known from the theory of tax incidence, the tax incidence in such monopoly markets depends on the specific shape of the demand function.

We now describe the experiment and then turn to the results, contrasting the outcomes with the theoretical considerations.

4 Experimental design, procedures, and related literature

Experimental design and procedures. Our experiment is based on a 2×2 factorial design, varying market power of firms on the supply side (monopoly vs. Bertrand competition), and distinguishing between simulated and real (that is, human) buyers on the demand side of a market. All sellers in our treatments are human decision-makers. We refer to the four treatments

[13] As bargaining theory suggests, however, narrowing down the range of mutually profitable transaction prices can also have a negative effect on efficiency (Myerson and Satterthwaite 1983).

[14] See, e.g., John and Klein (2003). They also address the issue why buyers may boycott even though each of them has a very small individual impact.

as follows. The monopoly treatment with simulated buyers is called "MonSim," whereas the monopoly treatment with real buyers is called "MonReal." Similarly, the treatment with Bertrand price competition and simulated demand is called "BertSim," whereas the Bertrand market with real buyers is called "BertReal."

In the instructions,[15] we used a non-neutral frame, with firms being referred to as "sellers" and consumers being referred to as "buyers." Subjects were informed that the experiment would consist of two parts and that they would first only be informed about the rules in the first part of the experiment. Only after completion of the first part were subjects informed about the rules of the second part. Each part of the experiment consisted of 10 decision rounds. The matching protocol used was a 'partner matching', that is, the same subjects interacted within one market throughout all 20 decision rounds. Earnings in the experiment were measured in "points" which, at the end of the experiment, were converted into real money (see below). In the following we describe the setting in each of the four treatments.

MonSim *Treatment* : On the supply side, there is one monopolist seller who offers to sell up to four units of a good in the market. On the demand side, there are four simulated buyers, each willing to buy one unit of the good and who have a monetary valuation for this unit of 24.5. At the beginning of each period the seller chooses a price (a non-negative integer) at which he would be willing to satisfy the demand of up to 4 units of the good. Sellers were informed that each of the four simulated buyers per market would then (independently) buy a unit of the good if and only if the price is not higher than 24.5. At the end of a period, the monopolist was informed about the number of units bought and about his own profit.

MonReal *Treatment* : The supply side is as in the MonSim treatment. On the demand side, there are four real buyers who can each buy one unit of the good and have an (induced) monetary valuation for this unit of 24.5, which was publicly known. After the monopolist made his decision about the price (at which he would be willing to satisfy the demand of up to 4 units of the good), buyers were informed about this price and then asked to independently and simultaneously make their purchase decision. At the end of a period, the monopolist was informed about the number of units bought (without any indication of the identity of buyers who bought or did not buy a unit) and about own profits. Buyers were informed about their own profit but not about the number of units sold by the monopolist.

[15] The experiment was administered in German. A complete set of translated instructions can be found in the Appendix.

BertSim *Treatment* : On the supply side, there are four sellers in each market who can each sell up to four units of the good in the market.[16] Sellers were informed about the four simulated buyers and how these simulated buyers would make their purchase decision given the market price. (Simulated buyers "acted" as described for the MonSim treatment.) At the beginning of each period, each of the four sellers was asked to independently and simultaneously choose a price at which he would be willing to satisfy the demand of up to 4 units of the good. Sellers knew that the lowest of the four chosen prices would be selected and passed on to buyers who would then make their purchase decisions. Subjects were informed that in case of more than one seller choosing the lowest price, the units that would be sold at this price would be equally divided among the sellers who chose the lowest price. At the end of a period, the sellers were informed about the lowest chosen price, the own number of units sold, and own profit.[17]

BertReal *Treatment*: Regarding sellers (buyers), the setting was as in the BertSim treatment (MonReal).

Each seller in each of the treatments had production costs of 6.5 points per unit sold in all periods of the experiment. Additionally, sellers had to pay a unit tax for each unit sold. This unit tax was equal to 2 points in the first phase of the experiment (10 periods). This feature was part of the instructions. In the second phase of the experiment, which also consisted of 10 periods, this unit tax was increased to 6 points per unit sold. After completion of the first phase of the experiment, a window appeared on subjects' screens informing them that the only change would be that sellers now had to pay a unit tax of 6 points per unit sold instead of 2 points and that all other rules would be the same as in the first phase of the experiment.

The experiment was programmed and conducted with the experiment software z-Tree (Fischbacher 2007) and run at the MELESSA lab of the University of Munich. The subjects were students from more than 40 different fields of study (112 subjects in total).[18] Each subject received an endowment of 25 points at the beginning of the experiment. This was done to cover possible losses. Subjects were informed that the sum of their earnings in points during the experiment plus their initial endowment would be converted into real money at the end of the experiment. In an effort to balance payments across treatments, we used an exchange rate of points to euros

[16] We use four sellers, as Dufwenberg and Gneezy (2000) found that the Bertrand solution predicts behavior well if there are three or more firms, whereas two sellers are more prone to collude.

[17] Only the lowest price, not the distribution of prices was reported to other players in order to make collusion more difficult, and, hence, come closer to a framework with perfect competition. Dufwenberg and Gneezy (2002) found that reporting of higher prices may facilitate collusion.

[18] The participants were recruited using the software ORSEE (Greiner 2004).

	Simulated Buyers	Real (Human) Buyers
Monopoly	"MonSim" 1 seller, 4 simulated buyers Number of markets: 10 Number of subjects: 10	"MonReal" 1 seller, 4 human buyers Number of markets: 6 Number of subjects: 30 ($= 6 \times 5$)
Bertrand	"BertSim" 4 sellers, 4 simulated buyers Number of markets: 6 Number of subjects: 24 ($= 6 \times 4$)	"BertReal" 4 sellers, 4 human buyers Number of markets: 6 Number of subjects: 48 ($= 6 \times 8$)

Table 1: Overview of the 2 by 2 factorial design

of, respectively, 200:1 (MonSim treatment), 25:1 (MonReal treatment), and 10:1 (BertSim and BertReal treatments). Table 1 summarizes basic information about the design.

Related experimental literature. Our analysis builds on a solid stock of knowledge from the literature on experimental market games, which cannot be surveyed here. Each of our treatments borrows from these insights, which also means that the setup of most of the respective experimental markets which we consider has been used in one or several other experiments in the context of other research questions.

Since sellers in our experiments make take-it-or-leave-it price offers to buyers, results on experimental posted-offer trading institutions are relevant. Monopoly markets using this institution are known to achieve prices "well above competitive levels, but on average, profits are significantly below theoretical monopoly levels." (Holt 1995, 381). A difference is that, next to the offer price, sellers in posted-offer markets typically also indicate the number of units they are willing to sell. We eliminated this feature in order to come closer to the textbook framework of a price-setting monopolist. The monopoly game we consider is also structurally related to the ultimatum game. From this literature (see, e.g., Güth 1995, or Roth 1995) it is known that proposers often propose the equal split, and that the probability of rejection by responders increases as offers decrease. These results shaped our hypotheses as regards the MonReal treatment.

There is also considerable evidence from experimental Bertrand markets. Experimental results in homogeneous markets show that while market prices stay above the competitive level in duopoly, they quickly converge to the competitive level when there are three or more firms in the market (see, e.g., Fouraker and Siegel 1963, and Dufwenberg and Gneezy 2002). Also, collusion among sellers is more difficult if only the lowest posted price is announced. For these reasons, we chose four sellers and posted only the lowest offer price. Tyran and Engelmann (2005) study consumer boycotts in a posted-offer market.[19] They study a market with three human sellers and five human buyers and ask whether a referendum among buyers about a boycott can make boycott a more effective kind of countervailing buyer power. They also study the role of a production cost increase for the effectiveness of boycott in treatments without a referendum and with a (individually non-binding) referendum. Although their research question is a completely different one, their base treatment (without a referendum) can be seen almost as the blueprint for our BertReal treatment, except for one difference: their suppliers have the option of withholding or limiting their supply (at a given price). We turned the suppliers into perfect Bertrand competitors by removing their option of limiting or withholding supply. This choice removes part of the power to threaten buyers, moving our market closer to a sequence of independent, perfectly competitive markets.[20]

Both in monopoly and oligopoly pricing games, the presence of human buyers leads to lower prices as compared to simulated demand. This has been attributed to actual or threatened demand withholding by human buyers (see Holt 1995 or Brown Kruse 2008 and the references therein). Countervailing buyer power may also become an issue with human buyers (see the overview by Ruffle 2009). These results provided suggestions for designing our treatments with automated and human buyers.

The economic effects of taxation in the context of markets is a core question in public finance. Who bears the burden of a unit sales tax? How does the allocation of this burden between buyers and sellers depend on the market conditions and the competition between sellers? Why is it easier for a Bertrand competitor to shift the burden of a tax than for a monopolist? What is the excess burden of a tax? And how does it depend on the prevailing market conditions? These questions are addressed in each and every textbook on taxation. Our analysis is—to the best of our knowledge—the first systematic experimental study that considers tax-burden shifting and the size of the excess burden of taxation as a function of market power.

[19] See also Ruffle (2000), Engle-Warnick and Ruffle (2005) and the survey by Ruffle (2009) on contervailing buyer power.

[20] Despite the wholly different research question in our paper, our results on Bert-Real also contribute to the research question in Tyran and Engelmann (2005). They find a substantial amount of boycott and we basically find no boycott. We find that both prices above marginal cost and boycott tend to disappear in a context without strategic supply withholding. Higher prices and the boycott behavior in their study may be driven by the assumption about sellers' withholding power.

5 Experimental results

We report the main results of the experiment in three steps. First, we analyze price-setting and buying behavior and test Hypotheses 1 and 2 on the pass-through of the tax burden from sellers to buyers. Second, we discuss the effect of the tax increase on producer surplus, consumer surplus, and tax revenue. Third, for the purpose of testing Hypothesis 3 on behavior under monopoly with real buyers, we estimate the demand curve in the MonReal treatment for "earlier" periods and check whether, based on this estimated demand, pricing behavior of monopolists can be predicted for "later" periods.

Price-setting and buying behavior We start with Table 2, which compares the equilibrium decisions for players who maximize their monetary payoffs with the average decisions observed in the experiment. Columns 2-4 show the results on price-setting and buyer behavior for the monopoly markets, while columns 5-7 show the corresponding results for the Bertrand markets. For each of the two market forms, one column shows the values predicted by theory while the two columns to the right of it show the results for markets with simulated and real (human) demand.[21] To purge the data of learning effects at the beginning of sessions, in Table 2 we report results of experienced behavior, i.e., from periods 6-10 of each phase of the experiment.[22] For all observed data, we test the null hypothesis of no difference between observed and theoretically predicted values.[23]

Let us first concentrate on prices. With respect to both Bertrand markets, we observe that the predictions of theory are quite accurately borne out by the data. That is, Bertrand competition pushes prices down to sellers' unit costs. The average prices in the first phase are extremely close to the predicted value of 9, and the average prices in the second phase are (almost) equal to 13, both with simulated and with real consumers. Accordingly, the price increase is equal to the tax increase, and this implies that the sellers can shift the entire tax burden to the buyers. The test statistics suggest that we cannot reject that there is a full pass-through of the tax increase: price

[21] Some entries in Tables 2 and 3 pertain to the behavior of automata. Still, for the sake of comparison with theoretical benchmarks as well as with outcomes in treatments with real buyers, we fill in all cells of Tables 2 and 3.

[22] Table 6 in Appendix A.1 illustrates potential learning effects by summarizing average prices in early and late periods for all treatments.

[23] The significance levels reported in Table 2 are the results of two-tailed one sample t-tests based on market averages; the test results are qualitatively the same when performing Wilcoxon signed-rank tests. For all tests, the unit of observation is the average observed market price over periods 6-10 (or periods 16-20) in one specific market. To simplify the exposition of the hypothesis testing, we use two-tailed tests throughout even if, for instance, the number of units bought cannot be greater than 4.

	Monopoly			Bertrand		
	Theory	MonSim	MonReal	Theory	BertSim	BertReal
Market Price	24	22.98	16.43***	9	8.97	8.90*
[tax = 2]		(0.62)	(1.09)		(0.08)	(0.05)
Market Price	24	23.42*	17.9***	13	13	12.97
[tax = 6]		(0.32)	(0.94)		(0)	(0.03)
Difference	0	0.44	1.47**	4	4.03	4.07
		(0.68)	(0.52)		(0.08)	(0.07)
No. units bought	4	3.92	3.03***	4	4	3.83*
[tax = 2]		(0.08)	(0.19)		(0)	(0.08)
No. units bought	4	4	3.23***	4	4	3.8
[tax = 6]		(0)	(0.16)		(0)	(0.10)
Difference	0	0.08	0.2	0	0	−0.03
		(0.08)	(0.23)		(0)	(0.06)

Note: Data from periods 6-10 of each phase. Standard errors in parentheses (based on market averages). All test statistics refer to two-tailed one-sample t-tests of whether the sample mean is equal to theoretically predicted value. The number of independent observations (=markets) is 10 for MonSim and 6 for the three other treatments. *** (**,*) significant at 1% (5%, 10%).

Table 2: Average observed prices and numbers of units bought

increases are not significantly different from 4, both for simulated and for real buyers.[24]

The outcome for monopoly markets with simulated demand is also largely in line with the theory prediction. Although firms in the first phase of the experiment price slightly below the textbook equilibrium, the average observed price increases only slightly with the tax rate. This price increase of 0.44 is not significantly different from zero (p-value is 0.536), and hence the results on monopoly pricing in MonSim provide evidence in favor of the theory prediction on the tax incidence effects.

In the monopoly markets with real demand, however, prices are much lower than the theory prediction of 24, both in the first and in the second phase of the experiment (16.43 and 17.9, respectively). Moreover, about 37% of the tax increase are passed forward to the consumers; this price increase by 1.47 is significantly different from zero (p-value is 0.037). Given that prices are lower than the monopoly price, the tax increase seemingly enables the monopolist to charge significantly higher prices, but the larger share of the tax burden is still borne by the firm.[25] Below we will analyze the pricing behavior of the monopolist in greater detail.

Similar results are obtained as regards buying behavior. Recall that in the treatments with simulated demand, consumers buy whenever the price is lower than their valuation of 24.5; consequently, demand is equal to 4 units in the treatments with simulated buyers.[26] Moreover, in BertReal, although being slightly lower than 4, the number of units bought is very close to the theoretically predicted value. In case of monopoly with real demand, however, buyer boycott exists, and the monopolist sells only about 3 out of the 4 units; in both phases, the number of units bought is significantly different from the theory prediction. Despite the fact that in MonReal the number of units bought increases with the tax increase, this increase of 0.2 units is not significantly different from zero.

Overall, we find support in favor of Hypothesis 1 on tax shifting with simulated buyers.

Result 1 *With simulated demand, there is full tax shifting in the Bertrand markets, but there is no significant tax shifting under monopoly.*

Moreover, including real buyers and potential demand withholding into the analysis does

[24] The p-values of the corresponding t-tests on market averages are 0.695 for BertSim and 0.363 for BertReal.

[25] Basically the same results on price-setting and tax shifting are obtained when running linear regressions with the price p_{it} in market i and period t as the dependent variable and controlling for possible non-independence within markets.

[26] In the first phase of MonSim, the number of units bought is only 3.92 and hence slightly below 4, because in one case a monopolist charged a price above the buyer valuation of 24.5.

not alter the results for tax shifting in Bertrand markets, but significantly affects the results in monopoly markets, in line with Hypothesis 2.

Result 2 *With real buyers, there is full tax shifting with Bertrand price competition and significant but incomplete tax shifting under monopoly.*

Material producer surplus and material consumer surplus From the results on price-shifting and buying decisions we can directly conclude on the effects of the tax increase on the payoffs of the different market participants. Since in the Bertrand markets the tax increase is fully passed forward to the consumers, producer surplus should not be affected by the tax increase, but consumer surplus should be reduced by the amount of the tax revenue. This is confirmed in Table 3, which summarizes firms' profits, buyers' monetary payoffs, tax revenues, and total surplus (which is being defined as the sum of firms' profits and buyers' payoffs plus tax revenue). Due to the specification of the demand curve, the quantity consumed and hence total surplus should be unaffected by the tax increase, and there should be no deadweight loss of taxation.[27] The results on buying decisions, however, have already shown that in the case of monopoly with real buyers there is a material deadweight loss caused by demand withholding.

In the treatments with Bertrand competition, firms' profits and buyers' payoffs are very close to the theory prediction. The real buyers (in BertReal) bear the entire share of the tax burden; the decrease in their profits (-15.98) from the first to the second phase is almost exactly equal to the additional tax revenues (15.13). Since firms' profits do not change, total surplus is unaffected by the tax increase and close to the theory prediction of 72 in both phases of the experiment. In BertSim, the results are even closer to the theory prediction (where one should keep in mind that here buyers' payoffs only refer to 'hypothetical payoffs').

In MonReal, monopoly profits are significantly lower and buyers' payoffs are significantly higher than the theory prediction, due to the lower-than-predicted price that the monopolist charges. Moreover, both monopoly profits and buyers' payoffs are reduced when the tax is increased (by -5.73 and -4.00, respectively). The tax revenue, however, increases by more than the reduction in producer and consumer surplus, and thus total surplus is higher when $t = 6$ than when $t = 2$. This increase of total surplus, which is statistically not significant, is caused by the effect of the tax increase on buying behavior: buyers are less inclined to withhold demand when the tax

[27] If buyers follow motives different from maximization of monetary payoffs, the effects of the tax increase on consumers' utility may, of course, be different from the effects on consumer surplus here measured as monetary payoffs.

	Monopoly			Bertrand		
	Theory	MonSim	MonReal	Theory	BertSim	BertReal
Total profits firm(s)	62	55.4*	22.42***	2	1.87	1.52**
[tax = 2]		(3.39)	(2.25)		(0.32)	(0.14)
Total profits firm(s)	46	43.68*	16.68***	2	2	1.77
[tax = 6]		(1.26)	(2.68)		(0)	(0.12)
Difference	−16	−11.72	−5.73***	0	0.13	0.25
		(3.52)	(1.85)		(0.32)	(0.25)
Total payoffs buyers	2	7.32*	26.12***	62	62.13	59.82
[tax = 2]		(2.68)	(4.67)		(0.32)	(1.41)
Total payoffs buyers	2	4.32*	22.12***	46	46	43.83
[tax = 6]		(1.26)	(3.70)		(0)	(1.25)
Difference	0	−3.00	−4.00	−16	−16.13	−15.98
		(2.89)	(2.82)		(0.32)	(0.99)
Tax revenue	8	7.84	6.07***	8	8	7.67*
[tax = 2]		(0.16)	(0.38)		(0)	(0.16)
Tax revenue	24	24	19.4***	24	24	22.80
[tax = 6]		(0)	(0.95)		(0)	(0.62)
Difference	16	16.16	13.33**	16	16	15.13
		(0.16)	(0.96)		(0)	(0.50)
Total surplus	72	70.56	54.60***	72	72	69.00*
[tax = 2]		(1.44)	(3.41)		(0)	(1.45)
Total surplus	72	72	58.20***	72	72	68.40
[tax = 6]		(0)	(2.85)		(0)	(1.86)
Difference	0	1.44	3.60	0	0	−0.60
		(1.44)	(4.05)		(0)	(1.11)

Note: Data from periods 6-10 of each phase. Standard errors in parentheses (based on market averages). All test statistics refer to two-tailed one-sample t-tests of whether the sample mean is equal to theoretically predicted value. The number of independent observations (=markets) is 10 for MonSim and 6 for the three other treatments. *** (**,*) significant at 1% (5%, 10%).

Table 3: Average observed firms' profits, buyers' payoffs, and tax revenue

is increased to $t = 6$, and the increase in units bought increases total surplus. In both phases, however, total surplus is significantly lower than the theory prediction, and there is a deadweight loss in the sense that total surplus realized is significantly lower than total surplus predicted by theory.[28] With simulated buyers (in MonSim), monopoly profits and the 'hypothetical payoffs' of the buyers are much closer to the theory prediction, and there is basically no deadweight loss.

Result 3 *The Bertrand markets with real buyers are (weakly) efficient. In the case of monopoly with real buyers, because of demand withholding, the total material surplus realized is lower than the theory prediction.*

To further illustrate the results in the monopoly treatments, let us compute the "monopoly effectiveness index": $M = (\pi^a - \pi^c)/(\pi^m - \pi^c)$, where π^a is actual profit, π^c is profit at the competitive equilibrium and π^m is monopoly profit calculated as in the textbook (Holt 1995).[29] For experienced behavior in the MonSim treatment, we find an average $M = 0.89$ (when $t = 2$) and $M = 0.95$ (when $t = 6$). For experienced behavior in treatment MonReal, these numbers are $M = 0.34$ (when $t = 2$) and $M = 0.33$ (when $t = 6$).[30]

Demand withholding and optimization in the monopoly case. We now turn to the outcomes that differ most noticeably from the textbook outcome: monopoly with real buyers. We will first estimate the demand function $D(p)$, given the monopolist's selling price. Then, we will test whether the monopolist reacts optimally to the observed demand. For this purpose, we will calculate the optimal price based on observed demand and compare it to the observed choice of the monopolist.

First, we estimate the buying behavior of the "average" buyer by means of a logit function of the form

$$\Pr(buy_{it}) = F(\beta_0 + \beta_1 p_{kt} + v_i + \varepsilon_{it}), \tag{2}$$

where buy_{it} is the acceptance decision of subject i in period t (buy_{it} equals 1 if subject i bought

[28] As discussed in the theory section, with demand withholding being absent, there should be no deadweight loss of taxation. In the presence of demand withholding, however, the tax increase might have different countervailing effects on the deadweight loss.

[29] For this index $M = 1$ ($M = 0$) means that the monopolist achieves monopoly (perfectly competitive) profits.

[30] For the final period in the markets reported in Smith (1981), Holt (1995) finds the following numbers: double-auction monopoly: $M = 0.36$; posted-bid monopoly: $M = 0.15$; posted-offer monopoly: $M = 1.0$. Plott (1989) remarks that the likely reason for the failure of the monopolist in the double auction to exercise market power is the fact that buyers in this institution do not behave passively as price takers but engage in withholding purchases. This behavior causes the monopolist to price more cautiously. This explanation is in line with the observations in our monopoly treatments, where, with human buyers in the Mon-Real treatment, we also observe demand withholding.

	Time interval used for estimation	β_0	β_1	Predicted p in period T	Observed p in period T
$T = 10$	$1, 2, ..., T - 1$	14.98^{***}	-0.83^{***}	16.06	16.33
		(2.90)	(0.17)		
$T = 20$	$11, 12, ..., T - 1$	34.26^{***}	-1.77^{***}	17.84	17.83
		(8.13)	(0.43)		
$T = 11$	$1, 2, ..., T - 1$	12.34^{***}	-0.67^{***}	16.32	18.00
		(2.37)	(0.14)		

Note: Columns 3-4 estimate buying behavior by means of a random-effects logistic regression. Standard errors in parentheses. The number of observations used is 216 in the rows labeled "T=10" and "T=20" and 240 in the row labeled "T=11". *** significant at 1%. Column 5 computes the profit-maximizing price based on the estimated demand function.

Table 4: Prediction of the monopoly price in period T based on observed buyer behavior in early periods (MonReal treatment)

a unit in period t, otherwise it equals 0), p_{kt} is the price set by monopolist k in period t, v_i is an individual-specific random effect, and F is the logit function $F(x) = 1/(1 + \exp(x))$. Recall that there are four real (human) buyers in each market in the MonReal treatment. Hence, the demand function, $D(p)$, of a typical monopolist in the MonReal treatment is simply given by $D(p) = 4F(p) = 4(1/(1 + \exp(\widehat{\beta}_0 + \widehat{\beta}_1 p)))$, where $\widehat{\beta}_0$ and $\widehat{\beta}_1$ are the estimated parameters in equation (2).[31]

Having estimated the average demand function in the MonReal treatment using the observations in periods $1, 2, ..., T - 1$ by means of equation (2), we then predict the average price chosen by monopolists in the MonReal treatment in period T as

$$\arg\max_p \{D(p)(p - c - t)\}$$

where $c = 6.5$ is the unit production cost and $t \in \{2, 6\}$ is the tax.

Table 4 should be read row by row. The entry in the first column indicates the period for which we want to predict the average price chosen by monopolists (i.e., period $T = 10$ in

[31] Note that estimating equation (2) models purchasing behavior of the average buyer. We refrain from estimating buyer behavior for each subject (and aggregating demand per market) for lack of a sufficient number of observations at the individual level.

row 2). The entry in the second column indicates the periods we use to estimate the demand functions monopolists faced in the past (i.e., periods $1, 2, ..., 9$ in row 2). The entries in the third and fourth column show the estimates of the parameters in the demand function (i.e., $\beta_0 = 14.98$ and $\beta_1 = -0.83$ in row 2). Finally, the entries in column 5 and 6 report, respectively, the predicted and the average observed price in period T (i.e., 16.06 and 16.33 in row 2).

The sign of the slope of the estimated demand function is given by the sign of the coefficient β_1. All estimates of β_1 reported in Table 4 are negative and highly significantly different from 0. We conclude that all demand functions reported in Table 4 are downward-sloping and are thus different from block demand (Hypothesis 3).

Next, consider row 2 (row 3), which shows the results concerning the prediction of the average price chosen in period 10 (period 20) using the information on buyer behavior in periods 1 to 9 (11 to 19). We find that the estimated average prices are very much on target. In fact, the predicted price for period 10 is 16.06, while we observe an average price of 16.33 in this period. Moreover, the predicted price for period 20 is 17.84, while the observed average price in this period is 17.83.[32] As an additional check, the last row in Table 4 predicts the price in period 11 (where the tax is increased to 6) based on buying behavior in periods 1 to 10 (where the tax is equal to 2). Perhaps not surprisingly, this exercise clearly fails, as the average observed price is about 1.7 units higher than the predicted price based on observed demand in the first phase. Summarizing we state the following result supporting Hypothesis 3:

Result 4 *With real buyers, the monopolist's demand curve is downward-sloping. In later periods, the monopolist chooses the price that maximizes his profit, based on observed buying decisions in earlier periods.*

6 Control treatments for MonReal

The results on price-setting and buying behavior under monopoly with real buyers show a difference to the theoretically predicted tax incidence effects. With the help of three control treatments, we will analyze the robustness of these results and check what could possibly cause the observed deviations from theory. Each of the three control treatments varies the original MonReal treatment along exactly one dimension. In particular, all control treatments employ human buyers.

[32] If we estimate the demand function based on buyer behavior in periods 1 to 8 (11 to 18) and predict the price for period 9 (period 19) we find again that observed prices are very close to predicted prices.

First, the buyer power in MonReal might be caused by the fact that buyers interact with the same seller over multiple rounds; consequently, in control treatment MonReal-Rand, we replace the fixed matching design by random matching across all participants of a session (4 sellers and 16 buyers) and randomly rematch one seller with four buyers in each round of the experiment. The remaining setup remains exactly as in MonReal.

Second, in MonReal, the capacity of the seller (4 units) is equal to the demand in his market; capacity constraints of the monopolist and hence 'competition' between the buyers might weaken buyer power and demand withholding and thus affect tax incidence. In the control treatment MonReal-Cap, the number of units that a monopolist can sell is reduced to 3. If at most 3 buyers decide to buy within a round and market, all buyers obtain a unit, but if all four buyers within a round and market decide to buy, the three buyers who will receive a unit of the good are randomly determined (such that the probability that a buyer doesn't obtain a unit is the same across all buyers).[33] Again, all other aspects of the experiment remain exactly as in MonReal.

Third, in order to obtain more information about the demand function, a treatment is conducted where, instead of reacting to a given price, in each round each buyer is asked to independently state the highest price (a non-negative integer) he is willing to pay for a unit of the good. This choice is made simultaneously with the pricing decision of the monopolist. Each buyer then automatically buys a unit of the good whenever his stated willingness-to-pay in this round is at least as high as the price chosen by the monopolist in the market. Otherwise, this control treatment MonReal-WTP is again completely identical to the MonReal treatment.[34]

The theory prediction concerning subject's choices in all three control treatments is the same as for the original MonReal treatment: the price charged should be 24 independently of the tax, and all buyers should decide to buy one unit. Table 5 summarizes the average prices and buying decisions in the four treatments (MonReal plus the three control treatments) and tests for all treatments whether observed average market prices and units bought are equal to the theory prediction.[35]

In all three control treatments, we observe a similar pattern of price-setting and buying

[33] Treatment MonReal-Cap does not allow buyers to compete directly with each other if the number of purchase decisions is larger than the capacity offered. For this reason the results are not directly comparable to results preseneted in Fehr and Schmidt (1999).

[34] The data includes 6 independent markets (6×5 subjects = 30 subjects) per treatment for MonReal-Cap and MonReal-WTP and 4 independent markets (4×20 subjects = 80 subjects) for the treatment MonReal-Rand with random matching among all participants of one session.

[35] Again, the significance levels reported in Table 5 are the results of two-tailed one sample t-tests based on market averages and are qualitatively the same when performing Wilcoxon signed-rank tests. For all tests, the unit of observation is the average observed market price over periods 6-10 (or periods 16-20) in one specific market.

	Theory	Monopoly with real buyers			
		MonReal	MonReal-Rand	MonReal-Cap	MonReal-WTP
Market Price	24	16.43***	17.35***	17.87***	16.23***
[tax = 2]		(1.09)	(0.33)	(0.96)	(1.34)
Market Price	24	17.90***	18.65***	19.77***	19.03***
[tax = 6]		(0.94)	(0.30)	(0.69)	(0.86)
Difference	0	1.47**	1.30**	1.90**	2.80***
		(0.52)	(0.32)	(0.70)	(0.66)
Demand (No. of units)[a]	4	3.03***	3.06***	3.33*	3.33**
[tax = 2]		(0.19)	(0.06)	(0.28)	(0.23)
Demand (No. of units)[a]	4	3.23***	3.36***	3.50*	3.13**
[tax = 6]		(0.16)	(0.10)	(0.23)	(0.22)
Difference	0	0.2	0.30**	0.17	−0.2
		(0.23)	(0.09)	(0.12)	(0.21)

Note: Data from periods 6-10 of each phase. Standard errors in parentheses (based on market averages). All test statistics refer to two-tailed one-sample t-tests of whether the sample mean is equal to theoretically predicted value. The number of independent observations (=markets) per treatment is 6 (4 for MonReal-Rand). *** (**,*) significant at 1% (5%, 10%).

[a] "Demand" refers to the buyers' buying decisions. In MonReal and MonReal-Rand demand is equal to turnover; in MonReal-WTP, it is the number of units demanded based on the stated willingness-to-pay. For MonReal-Cap, the number of units demanded should also be equal to 4, even if the turnover is limited to a maximum of 3 units.

Table 5: Price-setting and buying decisions in case of monopoly with real buyers

decisions. Prices are slightly higher than in the MonReal treatment (except for the first phase in MonReal-WTP), but none of the three control treatments differs significantly from MonReal.[36] In all treatments, prices are significantly lower than the theoretically predicted monopoly price. Most importantly, we observe similar tax incidence effects in all treatments. Firms are able to pass on a significant share of the tax increase to the consumers. This share is highest in the MonReal-WTP treatment (70%); in all other treatments, the pass-through rate is below 50%.

Moreover, buying decisions are similar across all treatments, and there is significant demand withholding: in all treatments the number of units bought is significantly different from the theory prediction. With random matching (MonReal-Rand) and capacity constraints (MonReal-Cap), demand withholding is reduced when the tax increases and hence total surplus increases with the tax increase, just as in MonReal. (Only the demand effect of tax increase in MonReal-Rand is significantly different from zero at the five percent level.) In the treatment where buyers had to state their willingness-to-pay (MonReal-WTP), demand withholding becomes slightly stronger in phase 2 (i.e., the number of units bought goes down), although the difference to phase 1 is not significant. The relatively high price in the second phase of MonReal-WTP seemingly comes at the cost of reducing the number of units sold. Overall, average buying behavior is quite similar in each of the control treatments, compared to the MonReal treatment.[37]

In Appendix A.2, we analyze *individual* buying behavior by means of a logistic regression as in (2) (similar as in Table 4). There, we find small and (mostly weakly) significant differences across treatments in the sense that the estimated demand curve in the control treatments lies above the estimated demand curve in MonReal. As Table 5 makes clear, however, these differences neither affect the pricing behavior of the monopolist nor the basic results on the tax incidence effects, which are extremely robust to the treatment variations.

For the MonReal-WTP treatment, the data on the number of units bought in Table 5 is based on the buyers' implicit decision whether to buy, depending on the stated willingness-to-pay. The data on the *maximum amount* that buyers are willing to pay reveals interesting additional facts. First, the individual willingness-to-pay reacts to the prices set by the monopolist: the price offered in the previous round has a significantly positive impact on a buyer's willingness to pay in

[36] Pairwise tests (t-tests or Wilcoxon rank-sum tests) based on market averages suggest that none of the observed prices in phase 1 and phase 2 are significantly different from the respective market prices in phase 1 and phase 2 of MonReal (all p-values are clearly larger than 0.1). This result is confirmed when we run linear regressions using individual-level data, controlling for possible non-independence within markets.

[37] Pairwise tests (t-tests or non-parametric tests based on market averages) on differences in the number of units bought reveal that none of the control treatments significantly differs from the MonReal treatment.

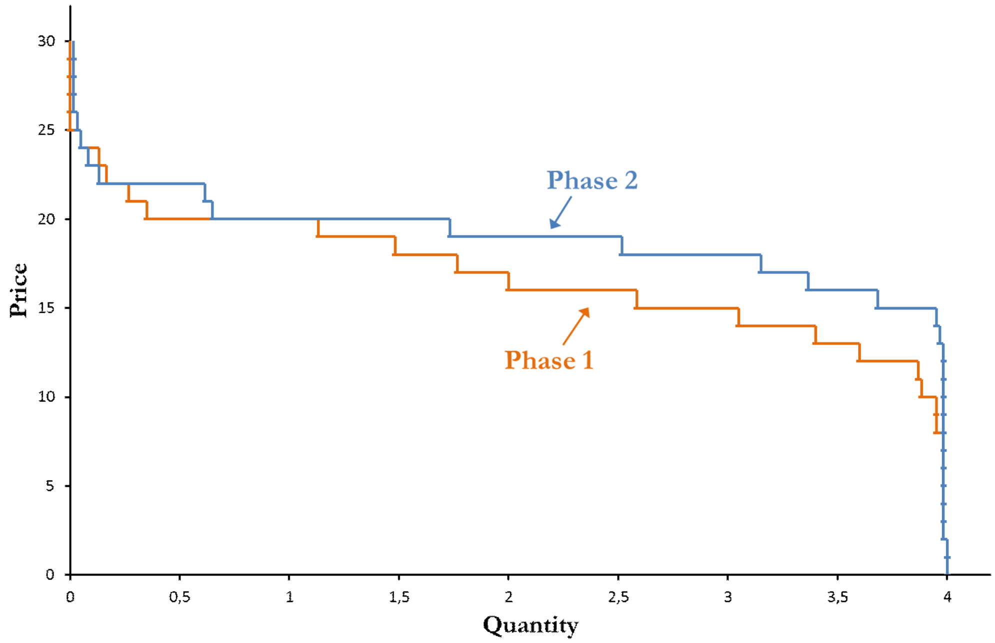

Figure 1: Effective demand curves in the MonReal-WTP treatment (for low-tax and high-tax phase, derived from the stated willingness-to-pay)

the current round. Hence, not only do monopolists react to the observed demand in their market, but buyers also learn about the monopolist's willingness to enforce high prices; throughout the rounds of the experiment, behavior of both sides of the market adjusts. Second, as Figure 1 shows, the tax increase shifts the demand curve to the right (the demand curve is derived from the stated willingness-to-pay). Hence, the higher prices charged by the monopolist after the tax increase are consistent with the higher reservation prices in the second phase of the experiment.

Overall, the three control treatments confirm our main findings for the case of monopoly with real buyers. Prices are significantly lower than in theory, and there is significant demand withholding. The tax increase weakens the consumers' propensity to withhold demand, and the monopolist uses the tax increase to raise the price and shifts a significant share of the increase in the tax burden to the consumers.

7 Conclusion

The experimental analysis in this paper tested the most salient predictions of public finance theory about the role of market power for tax incidence.

- We find that the tax incidence effects in Bertrand markets are an almost perfect mapping of results in public finance theory: a tax increase is fully shifted to the consumers via higher prices, where the equilibrium price stays very close to (tax-inclusive) marginal cost. This holds regardless of whether the buyers' decisions are simulated and deterministic, or whether buyers are real (human) players. Demand withholding or boycott does not play an important role and the outcome in the Bertrand markets is efficient.

- The experimental results in the case of monopoly with simulated buyers are also fully in line with tax incidence results for standard monopoly theory. The monopolist bears almost the entire burden of the tax increase.

- The presence of real buyers has a significant and negative impact on prices as predicted by a theory of buyer boycott. Buyers who are real (human) players are indeed willing to refuse to buy at prices that they consider too high, even if this price is lower than what they can obtain from the laboratory for forwarding the good to the laboratory. The observed monopoly prices are significantly below the monopoly price predicted by standard theory. Also, the monopolist significantly increases the market price as a reaction to the tax increase, and both the monopolist and the buyers bear a share in the additional tax burden. The observed price is consistent with profit-maximizing behavior of a monopolist who takes the buyers' possible boycott behavior into consideration and uses earlier purchase decisions to form a belief about buyer decisions. In the case of monopoly with real buyers, demand withholding leads to a loss in total material surplus. In theory, the tax increase might increase or reduce this deadweight loss caused by boycott behavior; in the experimental market we find that the tax increase reduces the deadweight loss.

The experimental analysis of the role of market power for the incidence of a tax was motivated by a sharp contrast between public perceptions and the predictions of public economic theory. In the public debate it is frequently argued that market power enables firms to maintain their profit margin in times of cost increases by passing a cost increase on to the consumers. In a similar vein, these public perceptions are expressed well by the participants in our experiment. At the end of the experiment, we asked the participants (among other questions) whether they (rather or fully) agreed to or (rather or fully) disagreed with the following statement:

> A monopolist is much more able to pass an increase in the VAT on to the consumers than a firm that is competing with many other firms.

Independent of the treatment, more than 50 percent of the participants fully agreed to this statement, and an additional 30 percent rather agreed. These numbers may be considered as surprisingly strong evidence for these perceptions (particularly given that these persons had just minutes before participated in one of the experimental sessions that produced the opposite results).

These public perceptions contrast strongly with textbook public finance theory. While providing a wealth of results for less clear-cut market conditions, textbook public finance makes precisely inverse predictions. It suggests that Bertrand competitors can completely shift the tax burden, whereas a monopolist cannot; it also offers a strong intuition for this result. Most of our experimental results contradict the widely held perceptions and are fully in line with the textbook intuition in public finance. This is true in particular if firms can firmly rely on (automated) demand choices determined purely by buyers' monetary rewards. If (human) buyers make purchase decisions, this causes strategic uncertainty. This effect does not affect the incidence results for Bertrand markets, but it changes the tax incidence of monopoly markets and brings the incidence outcomes closer to public perceptions; it places the monopolist firm in a position in which it may shift part of the tax on to buyers.

A Appendix

A.1 Average market prices (early versus late periods)

	Average market price			
	Phase 1 (low tax)		Phase 2 (high tax)	
	Periods 1-5	Periods 6-10	Periods 11-15	Periods 16-20
BertSim	9.33	8.97	12.73	13
	(0.58)	(0.08)	(0.65)	(0)
BertReal	8.63	8.9	13	12.97
	(0.45)	(0.05)	(0)	(0.03)
MonSim	20.46	22.98	23.18	23.42
	(1.28)	(0.62)	(0.79)	(0.32)
MonReal	15.97	16.43	18.07	17.9
	(0.86)	(1.09)	(0.77)	(0.94)
MonReal-Rand	16.21	17.35	19.03	18.65
	(0.60)	(0.33)	(0.36)	(0.30)
MonReal-Cap	17.3	17.87	19.7	19.77
	(0.96)	(0.96)	(0.93)	(0.69)
MonReal-WTP	16.53	16.23	18.83	19.03
	(1.22)	(1.34)	(0.85)	(0.86)

Note: This table summarizes average market prices in early and late periods of each phase in order to illustrate learning effects. Standard errors in parentheses (based on market averages).

Table 6: Average observed prices (early compared to late periods)

A.2 Estimation of individual buying behavior in the control treatments for MonReal

In this appendix, we analyze in greater detail individual buying behavior in the case of monopoly with real buyers, by means of a logistic regression as in (2) similar as in Table 4. The treatments included into the analysis are the original MonReal treatment and the three control treatments MonReal-Rand (random matching), MonReal-Cap (capacity constraints of the monopolist of 3 units), and MonReal-WTP (buying decisions made according to stated willingness-to-pay). The results are shown in Table 7 where we estimate buyer i's decision to buy in period t (buy_{it}) as a function of the price p_{kt} charged by monopolist k in period t, separately for the two phases of the experiment. In the estimations, we allow for treatment-specific intercepts and slopes: the coefficients α_0 and β_0 estimate intercept and slope for the MonReal treatment, while the coefficients $(\alpha_1, \alpha_2, \alpha_3)$ and $(\beta_1, \beta_2, \beta_3)$ measure *treatment differences* in intercept and slope, respectively, in the three control treatments. In all treatments, a higher market price has a significantly negative effect on the buying probability both for $t = 2$ and for $t = 6$, hence the demand curve is downward-sloping.[38] Comparing the estimated coefficients for the first and the second phase suggests that the tax increase shifts the demand curve to the right.[39]

Although the control treatments do not significantly differ from MonReal in terms of *average* number of units bought, there are weak differences in terms of intercept or slope and, in all three control treatments, the estimated demand curves lie above the estimated demand curve in MonReal. Moreover, the joint treatment effect (α_i and β_i, $i = 1, 2, 3$) is significantly different from zero in both phases of MonReal-Rand and MonReal-Cap (at the 5%-level); for MonReal-WTP, α_3 and β_3 are jointly significant only in phase 2 (at the 10%-level). The largest effect on the probability to buy arises in the treatment with capacity constraints where, for a given price, the probability to buy increases most strongly compared to MonReal. Capacity constraints lead to some sort of competition between the buyers, which makes them more likely to buy. Overall, however, the demand curves are very similar across the four treatments and, in particular, the slight differences in the observed demand do not have a significant effect on the average price charged by the monopolist when comparing the control treatments to the MonReal treatment.

[38] For all three control treatments we can reject the hypothesis that β_0 plus the respective coefficient β_i, $i \in \{1, 2, 3\}$ is equal to zero at the 1%-level.

[39] Estimating the probability of buying jointly for both phases and allowing for a separate intercept and slope in the second phase shows that the effect of the tax increase on intercept and slope is jointly different from zero for all treatments but the MonReal-Cap treatment.

Estimated equation: $\text{buy}_{it} = F(\alpha_0 + \boldsymbol{\alpha} \times \textsc{Control} + \beta_0 p_{kt} + \boldsymbol{\beta} \times p_{kt} \times \textsc{Control} + v_i + \varepsilon_{it})$		
Estimation results	Phase 1 only [tax = 2]	Phase 2 only [tax = 6]
α_0 (Constant)	11.63***	28.79***
	(1.98)	(4.90)
α_1 (MonReal-Rand)	4.49*	6.47
	(2.38)	(5.26)
α_2 (MonReal-Cap)	−3.32	−1.60
	(2.66)	(6.94)
α_3 (MonReal-WTP)	−1.49	−12.30*
	(2.66)	(6.69)
β_0 (p_{kt})	−0.63***	−1.47***
	(0.11)	(0.26)
β_1 (p_{kt} ∗ MonReal-Rand)	−0.19	−0.23
	(0.14)	(0.28)
β_2 (p_{kt} ∗ MonReal-Cap)	0.28*	0.24
	(0.15)	(0.35)
β_3 (p_{kt} ∗ MonReal-WTP)	0.09	0.70**
	(0.15)	(0.35)
N	1360	1360

Note: Random-effects logistic regression. Baseline category is the MonReal treatment. The vector CONTROL contains dummy variables for the three control treatments MonReal-Rand, MonReal-Cap, and MonReal-WTP. Standard errors in parentheses. *** (**,*) significant at 1% (5%, 10%).

Table 7: Buying decisions in the monopoly treatments with real buyers

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Instructions for the MonReal treatment

Welcome to this experiment!

General Information

- Please read these instructions carefully and completely.
- Please do not talk to your neighbors and keep quiet during the entire experiment.
- Raise your hand if you have a question. One of us will come to you.
- All participants in the experiment have been given the same instructions.

Introduction

- In this experiment you will repeatedly make decisions. By doing so you can earn money.
- Your gains are measured in Talers. How much you earn depends on your decisions and the decision of other participants.
- At the beginning of the experiment, each participant will receive an initial endowment of 25 Talers.
- At the end of the experiment your total sum of Talers will be determined by the sum of the initial endowment plus the number of Talers you earned in each round.
- At the end of the experiment you will receive 1 euro in cash for every 25 Talers. In addition, each participant will receive a participation fee of 4 euros.
- During the entire experiment, anonymity among participants and instructors will be kept.
- The experiment consists of two parts, each of which consists of 10 rounds. The rules for the first part will be explained now. The rules for the second part will be given after completion of the first part of the experiment.

Description of the experiment

- In this experiment you will act in a market in which there are sellers on one side and buyers on the other side of the market. In the following we will describe both sides of the market.

Sellers

- Sellers represent firms that manufacture and sell a product in this market.
- Each seller may sell up to four units of the product on the market. The production cost per unit sold is 6.50 Talers. In addition, each seller has to pay a tax of 2 Talers for each unit sold.
- In every round, each seller chooses the price at which he/she wishes to sell the product. This price must be a non-negative integer (0, 1, 2, 3 ...). By opting for this price, the seller declares that he/she wishes to sell up to four units of the product at this price.
- The seller's profit per round is calculated by the difference between the sales revenue and the cost:

Seller's profit = sales revenue - cost

- The sales revenue is equal to the chosen price multiplied by the number of units sold:

  Sales revenue = price $\times$ number of units sold

- The costs incurred are equal to the sum of production costs and tax per unit sold multiplied by the number of units sold:

  Cost = (cost of production per unit + tax per unit) $\times$ number of units sold
  = (6.50 + 2) $\times$ number of units sold
  = 8.50 $\times$ number of units sold

- So:

  Seller's profit
  = (sales revenue) - (cost)
  = (price $\times$ number of units sold) – (8.50 $\times$ number of units sold)
  = (price - 8.50) $\times$ number of units sold.

- Please note that a seller will make a loss if he sells the units at a price lower than the total sum of the costs and tax per unit (i.e., 8.50 Talers).

- There will be exactly one seller in each market. At the beginning of the experiment, one participant will be randomly assigned to a market as the seller and will remain as seller in this market in all rounds of the two parts of the experiment.

- At the beginning of each round, the seller of a market will choose a selling price. The price will be presented to the buyers, who then have to decide whether or not to buy at this price. The seller can sell the units (up to four) on the market.

Buyers

- Each buyer can buy exactly one unit on the market. The value of a unit bought is 24.50 Talers for each buyer. (The value is determined by the fact that the laboratory pays exactly this price to the buyers for each unit bought.)

- If a buyer purchases one unit of the product, the buyer's profit per round is the difference between the unit value and the purchase price:

  Buyer's profit = value - price = 24.50 - price

- There will be four buyers in each market. This means, the maximum demand in a market is four units.

- At the beginning of the experiment, four participants will be randomly assigned as buyers and will then remain as buyers in this market in all rounds of the two parts of the experiment.

- Once the seller has chosen a selling price at the beginning of a round, this price will be presented to the buyers. The buyers then have to decide whether or not to buy at this price.

  - If a buyer does not want to buy a unit at that price, he or she may press the push-button specifying “Do not Buy”.
  - If a buyer wants to buy a unit at that price, he or she can press the push-button indicating “Buy at this price”.
  - Please note that a buyer will make a loss if he/she buys a unit at a price that is higher than the value of a unit (i.e. higher than 24.50 Talers).

Sequence of actions in the experiment

- Each market consists of one seller (who can sell up to four units of the product) and four buyers (who can each purchase one unit). At the beginning of the experiment participants will be informed as to whether they are a seller or a buyer. The first phase of the experiment consists of 10 rounds. The sequence of a round in the first phase is as follows:
- At the beginning of each round, the seller of a market chooses a price at which he/she is obligated, depending on the demand, to sell four units. For this purpose, the seller chooses a non-negative integer (0, 1, 2, 3...) as a price, and confirms this by pressing the “OK” button.
- The price chosen by the seller will then be displayed to the buyers. Each buyer then has to independently decide whether or not to buy a unit of the product at the given price.
- To summarize the information in each round, the computer will then reveal the following information:
  - Seller: own chosen price, the number of own units sold and own profit.
  - Buyer: Lowest price chosen and the own profit.

Instructions for the MonSim treatment

Welcome to this experiment!

General Information

- Please read these instructions carefully and completely.
- Please do not talk to your neighbors and keep quiet during the entire experiment.
- Raise your hand if you have a question. One of us will come to you.
- All participants in the experiment have been given the same instructions.

Introduction

- In this experiment you will repeatedly make decisions. By doing so you can earn money.
- Your gains are measured in Talers. How much you earn depends on your decisions.
- At the beginning of the experiment, each participant will receive an initial endowment of 25 Talers.
- At the end of the experiment your total sum of Talers will be determined by the sum of the initial endowment and the number of Talers you have earned in each round.
- At the end of the experiment you will receive 1 euro in cash for every 200 Talers. In addition, each participant will receive a participation fee of 4 euros.
- During the entire experiment, anonymity among participants and instructors will be kept.
- The experiment consists of two parts, each of which consists of 10 rounds. The rules for the first part will be explained now. The rules for the second part will be given after completion of the first part of the experiment.

Description of the experiment

- In this experiment you will act in a market in which there are sellers on one side and buyers on the other side of the market. In the following we will describe both sides of the market.

Sellers

- Sellers represent firms that manufacture and sell a product in this market.
- Each seller may sell up to four units of the product on the market. The production cost per unit sold is 6.50 Talers. In addition, each seller has to pay a tax of 2 Talers for each unit sold.
- In every round, each seller chooses the price at which he/she wishes to sell the product. This price must be a non-negative integer (0, 1, 2, 3 ...). By opting for this price, the seller declares that he/she wishes to sell up to four units of the product at this price.
- The seller's profit per round is calculated by the difference between the sales revenue and the cost:

$$\text{Seller's profit} = \text{sales revenue - cost}$$

- The sales revenue is equal to the chosen price multiplied by the number of units sold:

$$\text{Sales revenue} = \text{price} \times \text{number of units sold}$$

- The costs incurred are equal to the sum of production costs and tax per unit sold multiplied by the number of units sold:

$$\begin{aligned}\text{Cost} &= (\text{cost of production per unit} + \text{tax per unit}) \times \text{number of units sold}\\ &= (6.50 + 2) \times \text{number of units sold}\\ &= 8.50 \times \text{number of units sold}\end{aligned}$$

- So:

$$\begin{aligned}&\text{Seller's profit}\\ &\quad = (\text{sales revenue}) - (\text{cost})\\ &\quad = (\text{price} \times \text{number of units sold}) - (8.50 \times \text{number of units sold})\\ &\quad = (\text{price} - 8.50) \times \text{number of units sold.}\end{aligned}$$

- Please note that a seller will make a loss if he/she sells the units at a price lower than the total sum of the costs and tax per unit (i.e., 8.50 Talers).
- There will be exactly one seller in each market. At the beginning of the experiment, one participant will be randomly assigned to a market as the seller and will remain as seller in this market in all rounds of the two parts of the experiment.
- At the beginning of each round, the seller of a market will choose a selling price. The price will be presented to the buyers, who then have to decide whether or not to buy at this price. The seller can sell the units (up to four) on the market.

Buyers

- Each buyer can buy exactly one unit on the market. The value of a unit bought is 24.50 Talers for each buyer. (The value is determined by the fact that the laboratory pays exactly this price to the buyers for each unit bought.)
- If a buyer purchases one unit of the product, the buyer's profit per round is the difference between the unit value and the purchase price:

$$\text{Buyer's profit} = \text{value - price} = 24.50 - \text{price}$$

- There will be four buyers in each market. This means, the maximum demand in a market is four units.
- There are no real buyers in this experiment. Instead, the buyers in all rounds of the two parts of the experiment are simulated by the computer. There are four computer-simulated buyers.
- Once the seller has chosen a selling price at the beginning of a round, this price will be presented to the simulated buyers. The simulated buyers then have to decide whether or not to buy at this price.

  - None of the simulated buyers will purchase a unit of the product if the price is higher than the 24.50 value of a unit.
  - Each of the four simulated buyers will purchase one unit of the product at a price that is less than or equal to the 24.50 value of a unit.

Sequence of actions in the experiment

- Each market consists of one seller (who can sell up to four units of the product) and four simulated buyers (who can each purchase one unit). The first phase of the experiment consists of 10 rounds. The sequence of a round in the first phase is as follows:
- At the beginning of each round, the seller of a market chooses a price at which he/she is obligated, depending on the demand, to sell four units. For this purpose, the seller chooses a non-negative integer (0, 1, 2, 3...) as a price, and confirms this by pressing the "OK" button.
- The price chosen by the seller will then be displayed to the buyers. Each buyer then has to independently decide whether or not to buy a unit of the product at the given price.
- To summarize the information in each round, the computer will then reveal the following information:
  - Chosen price, the number of units sold, and own profit.

Instructions for the BertReal treatment

Welcome to this experiment!

General Information

- Please read these instructions carefully and completely.
- Please do not talk to your neighbors and keep quiet during the entire experiment.
- Raise your hand if you have a question. One of us will come to you.
- All participants in the experiment have been given the same instructions.

Introduction

- In this experiment you will repeatedly make decisions. By doing so you can earn money.
- Your gains are measured in Talers. How much you earn depends on your decisions and the decision of other participants.
- At the beginning of the experiment, each participant will receive an initial endowment of 25 Talers.
- At the end of the experiment your total sum of Talers will be determined by the sum of the initial endowment plus the number of Talers you have earned in each round.
- At the end of the experiment you will receive 1 euro in cash for every 25 Talers. In addition, each participant will receive a participation fee of 4 euros.
- During the entire experiment, anonymity among participants and instructors will be kept.
- The experiment consists of two parts, each of which consists of 10 rounds. The rules for the first part will be explained now. The rules for the second part will be given after completion of the first part of the experiment.

Description of the experiment

- In this experiment you will act in a market in which there are sellers on one side and buyers on the other side of the market. In the following we will describe both sides of the market.

Sellers

- Sellers represent firms that manufacture and sell a product in this market.
- Each seller may sell up to four units of the product on the market. The production cost per unit sold is 6.50 Talers. In addition, each seller has to pay a tax of 2 Talers for each unit sold.
- In every round, each seller chooses the price at which he/she wishes to sell the product. This price must be a non-negative integer (0, 1, 2, 3 ...). By opting for this price, the seller declares that he/she wishes to sell up to four units of the product at this price.
- The seller's profit per round is calculated by the difference between the sales revenue and the cost:

Seller's profit = sales revenue - cost

- The sales revenue is equal to the chosen price multiplied by the number of units sold:

  Sales revenue = price $\times$ number of units sold

- The costs incurred are equal to the sum of production costs and tax per unit sold multiplied by the number of units sold:

$$\begin{aligned} \text{Cost} &= (\text{cost of production per unit} + \text{tax per unit}) \times \text{number of units sold} \\ &= (6.50 + 2) \times \text{number of units sold} \\ &= 8.50 \times \text{number of units sold} \end{aligned}$$

- So:

$$\begin{aligned} &\text{Seller's profit} \\ &\quad = (\text{sales revenue}) - (\text{cost}) \\ &\quad = (\text{price} \times \text{number of units sold}) - (8.50 \times \text{number of units sold}) \\ &\quad = (\text{price} - 8.50) \times \text{number of units sold.} \end{aligned}$$

- Please note that a seller will make a loss if he/she sells the units at a price lower than the total sum of the costs and tax per unit (i.e., 8.50 Talers).
- There will be four sellers in each market. At the beginning of the experiment, four participants will be randomly assigned to a market as sellers, and these sellers will remain as sellers in this market in all rounds of the two parts of the experiment.
- At the beginning of each round, all the sellers of a market will simultaneously and independently choose a selling price. The prices are then recorded and compared. Only the lowest of the prices chosen by the sellers will be presented to the buyers, who then have to decide whether or not to buy at this price. This means that only the seller with the lowest price can sell his units (up to four) on the market. If more than one seller chooses this lowest price, the units to be sold will be evenly divided between these sellers.

Buyers

- Each buyer can buy exactly one unit on the market. The value of a unit bought is 24.50 Talers for each buyer. (The value is determined by the fact that the laboratory pays exactly this price to the buyers for each unit bought.)
- If a buyer purchases one unit of the product, the buyer's profit per round is the difference between the unit value and the purchase price:

  Buyer's profit = value - price = 24.50 - price

- There will be four buyers in each market. This means, the maximum demand in a market is four units.
- At the beginning of the experiment, four participants will be randomly assigned as buyers and will then remain buyers in this market in all rounds of the two parts of the experiment.

- Once the sellers have simultaneously and independently chosen their selling price at the beginning of a round, the lowest of the four prices will be selected and presented to the buyers. The buyers then have to decide whether or not to buy at this price.
  - If a buyer does not want to buy a unit at that price, he or she may press the push-button specifying "Do not Buy".
  - If a buyer wants to buy a unit at that price, he or she can press the push-button indicating "Buy at this price".
  - Please note that a buyer will make a loss if he/she buys a unit at a price that is higher than the value of a unit (i.e. higher than 24.50 Talers).

Sequence of actions in the experiment

- Each market consists of four sellers (who can each sell up to four units of the product) and four buyers (who can each purchase one unit). At the beginning of the experiment participants will be informed as to whether they are a seller or a buyer. The first phase of the experiment consists of 10 rounds. The sequence of a round in the first phase is as follows:
- At the beginning of each round, the sellers of a market independently choose a price at which they are obligated, depending on the demand, to sell four units. For this purpose, each seller chooses a non-negative integer (0, 1, 2, 3...) as a price, and confirms this by pressing the "OK" button.
- The lowest of the prices chosen by the sellers will then be displayed to the buyers. Each buyer then has to independently decide whether or not to buy a unit of the product at the given price.
- To summarize the information in each round, the computer will then reveal the following information:
  - Seller: own chosen price, the lowest price chosen, the number of own units sold and the own profit.
  - Buyer: Lowest price chosen and own profit.

Instructions for the BertSim treatment

Welcome to this experiment!

General Information

- Please read these instructions carefully and completely.
- Please do not talk to your neighbors and keep quiet during the entire experiment.
- Raise your hand if you have a question. One of us will come to you.
- All participants in the experiment have been given the same instructions.

Introduction

- In this experiment you will repeatedly make decisions. By doing so you can earn money.
- Your gains are measured in Talers. How much you earn depends on your decisions and the decision of other participants.
- At the beginning of the experiment, each participant will receive an initial endowment of 25 Talers.
- At the end of the experiment your total sum of Talers will be determined by the sum of the initial endowment plus the number of Talers you have earned in each round.
- At the end of the experiment you will receive 1 euro in cash for every 10 Talers. In addition, each participant will receive a participation fee of 4 euros.
- During the entire experiment, anonymity among participants and instructors will be kept.
- The experiment consists of two parts, each of which consists of 10 rounds. The rules for the first part will be explained now. The rules for the second part will be given after completion of the first part of the experiment.

Description of the experiment

- In this experiment you will act in a market in which there are sellers on one side and buyers on the other side of the market. In the following we will describe both sides of the market.

Sellers

- Sellers represent firms that manufacture and sell a product in this market. Each seller may sell up to four units of the product on the market. The production cost per unit sold is 6.50 Talers. In addition, each seller has to pay a tax of 2 Talers for each unit sold.
- In every round, each seller chooses the price at which he/she wishes to sell the product. This price must be a non-negative integer (0, 1, 2, 3 ...). By opting for this price, the seller declares that he/she wishes to sell up to four units of the product at this price.
- The seller's profit per round is calculated by the difference between the sales revenue and the cost:

$$\text{Seller's profit} = \text{sales revenue - cost}$$

- The sales revenue is equal to the chosen price multiplied by the number of units sold:

$$\text{Sales revenue} = \text{price} \times \text{number of units sold}$$

- The costs incurred are equal to the sum of production costs and tax per unit sold multiplied by the number of units sold:

$$\begin{aligned}\text{Cost} &= (\text{cost of production per unit} + \text{tax per unit}) \times \text{number of units sold}\\ &= (6.50 + 2) \times \text{number of units sold}\\ &= 8.50 \times \text{number of units sold}\end{aligned}$$

- So:

$$\begin{aligned}&\text{Seller's profit}\\ &\quad= (\text{sales revenue}) \text{ - } (\text{cost})\\ &\quad= (\text{price} \times \text{number of units sold}) - (8.50 \times \text{number of units sold})\\ &\quad= (\text{price - } 8.50) \times \text{number of units sold.}\end{aligned}$$

- Please note that a seller will make a loss if he sells the units at a price lower than the total sum of the costs and tax per unit (i.e., 8.50 Talers).
- There will be exactly four sellers in each market. At the beginning of the experiment, four participants will be randomly assigned to a market as sellers, and these sellers will remain as sellers in this market in all rounds of the two parts of the experiment.
- At the beginning of each round, all the sellers of a market will simultaneously and independently choose a selling price. The prices are then recorded and compared. Only the lowest of the prices chosen by the sellers will be presented to the buyers, who then have to decide whether or not to buy at this price. This means that only the seller with the lowest price can sell his units (up to four) on the market. If more than one seller chooses this lowest price, the units to be sold will be evenly divided between these sellers.

Buyers

- Each buyer can buy exactly one unit on the market. The value of a unit bought is 24.50 Talers for each buyer. (The value is determined by the fact that the laboratory pays exactly this price to the buyers for each unit bought.)
- If a buyer purchases one unit of the product, the buyer's profit per round is the difference between the unit value and the purchase price:

$$\text{Buyer's profit} = \text{value - price} = 24.50 \text{ - price}$$

- There will be four buyers in each market. This means, the maximum demand in a market is four units.
- There are no real buyers in this experiment. Instead, the buyers in all rounds of the two parts of the experiment are simulated by the computer. There are four computer-simulated buyers.

- Once the sellers have simultaneously and independently chosen their selling price at the beginning of a round, the lowest of the four prices will be selected and presented to the buyers. The simulated buyers then have to decide whether or not to buy at this price.
  - None of the simulated buyers will purchase a unit of the product if the price is higher than the 24.50 value of a unit.
  - Each of the four simulated buyers will purchase one unit of the product at a price that is less than or equal to the 24.50 value of a unit.

Sequence of actions in the experiment

- Each market consists of four sellers (who can each sell up to four units of the product) and four simulated buyers (who can each purchase one unit). The first phase of the experiment consists of 10 rounds. The sequence of a round in the first phase is as follows:
- At the beginning of each round, the sellers of a market independently choose a price at which they are obligated, depending on the demand, to sell four units. For this purpose, each seller chooses a non-negative integer (0, 1, 2, 3...) as a price, and confirms this by pressing the "OK" button.
- The lowest of the prices chosen by the sellers will then be displayed to the buyers. Each buyer then has to independently decide whether or not to buy a unit of the product at the given price.
- To summarize the information in each round, the computer will then reveal the following information:
  - Own chosen price, the lowest price chosen, the number of own units sold and own profit.