TAX INCIDENCE: DO INSTITUTIONS MATTER? AN EXPERIMENTAL STUDY

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By James C. Cox[A], Mark Rider[A], and Astha Sen[A]

[A] Experimental Economics Center and the Department of Economics, Andrew Young School of Policy Studies, Georgia State University, 14 Marietta Street, N.W., Atlanta, GA 30303. Partial financial support was provided by the National Science Foundation (grant number SES-0849590). Corresponding author: Mark Rider, office phone (404) 413-0227 and email address mrider@gsu.edu.

Abstract

There is perhaps no more important question in public finance than who ultimately bears the burden of a tax. According to tax incidence theory, the long-run incidence of a unit tax in competitive markets is independent of the assignment of the liability to pay tax. Moreover, the theory is silent on the possible effects of market institutions on tax incidence. We report data from an experiment designed to address two questions. Is tax incidence independent of the assignment of the liability to pay tax in experimental markets? Is tax incidence independent of the market institution in experimental markets? We conduct laboratory experiments, using double auction and posted offer markets. Based on the results of Kolmogorov-Smirnov tests of experimental market prices, we conclude that the answer to both questions is an emphatic "no." We report evidence that the observed differences from the theoretical values are economically significant.

1. Introduction

To understand the distributional effects of a tax, it is necessary to know who ultimately bears the burden of that tax. The theory of tax incidence concerns itself with answering this very question, and there may be no more important question in public finance. According to the standard theory, the incidence of a tax in long-run competitive equilibrium has nothing to do with the statutory assignment of the liability to pay tax. Rather, it depends on the relative elasticities of supply and demand; the more inelastic of the two ultimately bears the greater tax burden. This hypothesis is referred to in the literature as liability side equivalence (LSE).

The economic intuition for this conclusion is straightforward. Suppose, for example, that a firm is liable to pay tax on every unit sold. The firm can try to shift the tax forward onto the consumer through higher prices. The ability of the firm to do so, however, is limited by the own-price elasticity of demand for the good. If demand is sufficiently inelastic relative to supply, the change in quantity demanded will be small in response to a given increase in the price. In this case, the firm will find it profitable to shift much of the tax burden onto consumers. If, on the other hand, demand is elastic relative to supply, increasing the price to shift the tax will lead to a large decrease in the quantity demanded. In this case, the firm will not find it profitable to shift as much of the tax onto the consumer as in the inelastic case. From this perspective, nothing changes if the consumer is assigned the liability to pay the tax rather than the seller. Of course, the firm has not exhausted all of its options; it could also attempt to shift the tax backward onto the suppliers of factors of production. Again, according to the standard theory, the firm’s ability to do so depends on the relative price elasticities of factor supplies and demands.

There is a growing literature that suggests matters may not be quite so simple; that in fact, institutional, informational, and behavioral factors may influence tax incidence.[1] Furthermore, markets need institutions to function. These institutions specify how buyers and sellers interact to determine prices and quantities. Different market institutions are known to have different price formation and quantity determination properties, and these properties may affect the incidence and excess burden of a tax.[2] Yet, there is no accounting in the theoretical literature for the potential influence of the type of market institution on tax incidence in competitive markets.

There are a number of econometric studies that report evidence of tax over-shifting, which is not consistent with the predictions of the standard theory. For example, Hanson and Sullivan (2009) use the occasion of a $1 per pack increase in the cigarette excise tax in Wisconsin to estimate the incidence of a cigarette tax. They find that this tax change increased the price per pack by $1.08 to $1.17, which they interpret to be evidence of tax over-shifting. Using data for multiple states, Harris (1987) and Keeler et al. (1996) report similar evidence of over-shifting of excise taxes on cigarettes. Finally, Besley and Rosen (1999) find that sales taxes are over-shifted for more than half of the products sold at retail.[3] The standard theory of tax incidence does not predict tax over-shifting in long-run competitive equilibrium.

[1] Using a laboratory experiment, Sausgruber and Tyran (2005) test the "Mill hypothesis" that the burden of an indirect tax may differ from that of a direct tax because the former is less visible. In a related study using a field experiment, Chetty et al. (2009) examine the impact of tax salience on tax incidence. Saez et al. (2012) test the LSE hypothesis using a natural experiment involving the assignment of the liability to remit payroll taxes in Greece. Finkelstein (2009) reports evidence that salience influences the elasticity of demand for tolled roads.

[2] See, for examples: Williams (1973), Plott and Smith (1978), Hong and Plott (1982), Smith (1982b), and Ketcham et al. (1984).

[3] Poterba (1996) reports evidence of over-shifting of sales taxes in Chicago and negative-shifting in Atlanta. Sumner and Wohlgenant (1985) report evidence of full-shifting of taxes; whereas, Ashenfelter and Sullivan (1987) contend that excise tax increases do not consistently lead to increases in retail prices. Saez et al. (2012) report evidence from a natural experiment created by a change in the payroll tax rate in Greece. They find that the assignment of the liability to pay tax influences the incidence of a payroll tax.

In the face of reported findings that contradict long-established theoretical results, a natural reaction is to find fault with the econometric strategies that result in such findings. Critics point out that taxes are used to finance government services and contend that the estimates may be inconsistent unless such benefits are accounted for in the econometric specification. Others contend that the estimates reported in the literature are short-run rather than long-run measures of tax incidence, and critics also point out that the transaction costs are not zero in these markets, as assumed by the theory.

Laboratory experiments are a natural alternative to econometric studies using observational data for testing the LSE hypothesis because the experimenter has control over the environment and can change one variable at a time. We are not the first to propose testing the LSE hypothesis in a laboratory setting. Kachelmeier et al. (1994), Kerschbamer and Kirchsteiger (2000), Borck et al. (2002), Riedl et al. (2005), and Ruffle (2005) test the LSE hypothesis in laboratory settings using a variety of different taxes and market institutions.

Kerschbamer and Kirchsteiger (2000) test the LSE hypothesis by imposing a tax on either the proposer or the responder in a one-stage ultimatum bargaining game. They contend that the LSE hypothesis should hold in the tax version of the ultimatum game as long as the fairness norm threshold below which offers are rejected remains unaffected by a change in the statutory assignment of the liability to pay the tax. Based on the results of their experiments, they reject the LSE hypothesis. To explain this finding, they hypothesize that the assignment of the liability to pay tax may lead those with the legal responsibility for remitting the tax to the government to feel a moral duty to bear the tax economically. There is no market institution in this experiment.

Riedl and Tyran (2005) test the aforementioned hypothesis, using a gift-exchange game. They contend that LSE should hold in gift-exchange games when gross wages adjust to changes in taxes and market participants are exclusively concerned with net-of-tax profits and wages. They test the LSE hypothesis in a gift-exchange game where social norms may cause LSE to breakdown. In contrast to Kerschbamer and Kirschsteiger, Riedl and Tyran cannot reject the LSE hypothesis. There is no market institution in this experiment.

Kachelmeier et al. (1994) use a complicated experimental design to test the LSE hypothesis involving two interrelated, double auction markets, three agents (customers, retailers, and wholesalers), and three different tax instruments (an ad valorem tax levied on customers, a turnover tax levied on retailers, and a value-added tax levied on wholesalers and retailers). In their experimental design, there are 10 periods without a tax; then, there are 10 periods with one of the tax instruments described above. They conduct 10 market sessions. They cannot reject the LSE hypothesis. Borck et al. (2002) test the LSE hypothesis in posted offer markets, using a per unit tax. In their experimental design, there is no tax in the first 12 periods; they introduce a unit tax in periods 13 through 24. They conduct 10 market sessions. They also conduct two market sessions using a double auction market design. Based on the results from their experiments, they cannot reject the LSE hypothesis for either market institution. However, they do not report whether tax incidence differs between the two market institutions.

Ruffle (2005) tests the LSE hypothesis for taxes and subsidies. They use a pit market where at least eight pairs of buyers and sellers participate in all experiments.[4] All sessions consist of 19 three-minute trading periods. During the first eight periods, subjects participate in an ordinary pit market, with no tax or subsidy. Beginning in period 9, a single change is introduced, namely a 10-

[4] A pit market closely resembles a double auction market. The two institutions differ in the way bids and asks are organized. In a pit market, traders negotiate directly with whomever they choose from the other side of the market, with participants freely exchanging bids and asks between them until a transaction price is agreed upon. In the double auction market, bids and asks are publicly recorded. In a double auction market, actual trade occurs when a seller accepts the most attractive bid price, or a buyer accepts the most attractive offer price among the outstanding bid and offer prices.

unit tax (subsidy) on either the buyers or the sellers. They find strong support for the LSE hypothesis for both subsidies and taxes.

In each of the experimental designs with market institutions described above, the experiment begins with a no-tax treatment in the initial market periods; then, a tax is introduced and the market experiment proceeds for an equal number of periods as in the initial no-tax treatment. In these experiments, there is a striking difference between the initial rounds of the no-tax treatment and those of the tax treatment. The trading prices in the initial rounds of the no-tax treatment are rather noisy, and it takes a number of rounds before prices begin to stabilize and converge to an equilibrium. In contrast, the initial rounds of the tax treatment converge almost immediately to an equilibrium. This raises the question of whether the LSE hypothesis holds in the absence of an initial no-tax treatment; after all, the standard theory says nothing about the initial rounds involving a no-tax treatment.

Our experimental design differs from the existing literature in a number of important ways. We introduce a unit tax in the first trading period and maintain that tax throughout all 30 trading periods. In addition to testing LSE for two market institutions, we test whether the incidence of a unit tax is the same for both market institutions – double auction and posted offer markets. We also calculate the excess burden due to the unit tax for each of the four treatments that result from our 2×2 design. Our underlying research question therefore is whether two prominent features of a controlled experimental economy – the assignment of the liability to pay tax and the type of market institution – influence the incidence of a tax in competitive markets.

More specifically, we conduct laboratory experiments comparing two market institutions, computerized double auction (DA) and posted offer (PO) markets, to investigate whether tax incidence is independent of the assignment of the liability to pay tax and the type of market institution. The rules of the computerized DA market in our experiments are essentially the same as those that govern trading on the New York Stock Exchange and on many organized futures markets. An experimental DA market is open for a specified interval of time; buyers are free to announce at any instant a bid price for the commodity they wish to buy; and sellers are free to announce an offer price for the commodity they wish to sell. In the simplified DA markets used in many experiments, including ours, each bid, offer, or contract is for a single unit. Actual trade occurs when a seller accepts the most attractive bid price, or a buyer accepts the most attractive offer price among the outstanding bid and offer prices.

The rules of the computerized PO market in our experiments are similar to those that govern most of the consumer goods markets in developed countries. Think, for example, of a supermarket or department store. The seller posts a sales price for a commodity and may also limit the quantity they are willing to sell at that price. Buyers may compare prices available to them from different sellers and make the decision to buy or not to buy a given commodity from a given seller at the posted price. The computerized PO market in our experiments is similar to this field institution.

The choice of DA and PO markets are particularly well suited to the research questions at hand. Smith (1976b), Smith et al. (1982), Williams (1980), and Smith and Williams (1983) report the robust result that DA markets converge rapidly to a competitive equilibrium thus exhausting the potential gains from trade. In other words, DA markets achieve the Pareto efficient resource allocation of competitive market theory. It would seem that DA markets give the standard theory of tax incidence the best chance of success. In contrast, Plott and Smith (1978), Williams (1980), Hong and Plott (1982), Smith (1982b), and Ketcham et al. (1984) report evidence that PO markets produce prices that converge to the competitive equilibrium price from above and more slowly than in DA markets. PO markets also yield less efficient allocations than DA markets. Consequently, the standard theory of tax incidence seems less likely to apply to PO markets. However, PO exchange is the most common retail market institution in developed countries; thus, it is important to investigate the effect of this market institution on tax incidence.

Our experimental design includes four treatments that use the same induced, stationary supply and demand schedules: (1) a double auction market with a unit tax on the buyer (DATB); (2) a double auction market with a unit tax on the seller (DATS); (3) a posted offer market with a unit tax on the buyer (POTB); and (4) a posted offer market with a unit tax on the seller (POTS). Tax incidence theory is silent about the role market institutions play in determining who ultimately bears the burden of a tax. The theory predicts that the incidence and excess burden of a unit tax is independent of the assignment of liability to pay tax.

To test the LSE hypothesis, we conduct Kolmogorov-Smirnov (K-S) two-sample tests using pairwise comparisons of distributions of average buyer prices from the four experimental treatments. In contrast to the predictions of tax incidence theory, the K-S tests reject the LSE hypothesis at conventional levels of significance. The K-S tests also reject the hypothesis at conventional levels of significance that the type of market institution has no effect on the distribution of average buyer prices. In short, we report evidence that the assignment of the liability to pay tax and the type of market institution each has a statistically and economically significant effect on tax incidence in competitive markets.

The remainder of this paper is organized as follows. The next section describes our experimental design in greater detail, and the subsequent section explains the results. We conclude in the final section.

2. Experimental design and protocol

Our experimental design tests the ability of a widely accepted economic theory to predict the influence of changes in the type of market institution and in the assignment of the liability to pay tax on tax incidence. Following Smith (1976a, 1982a), we induce stationary demand and supply functions for a fictitious commodity. We use a balanced design in which tax incidence theory predicts that the economic burden of a unit tax on a homogeneous good will be equally shared between buyers and sellers, independently of the assignment of the liability to pay tax.[5]

As previously noted, the theory makes no prediction regarding the influence of a change in the type of market institution on the incidence of a tax. To gauge the impact of the market institution, we change the market institution from a DA to a PO market, keeping the assignment of the liability to pay tax the same. Similarly, we change the assignment of the liability to pay tax from the seller to the buyer, keeping the market institution the same, in order to gauge the impact of this change on the incidence of a tax. The result is a 2×2 design with a total of four treatments. This illustrates the advantage of laboratory experiments. They are performed in well-defined, controlled environments, where one variable at a time is changed to measure its impact on the outcome of interest. We proceed below by describing our basic experimental design.

We conduct a total of four sessions, with each session devoted to a distinct treatment. The subject's role is randomly assigned by a computer at the beginning of each session and remains the same throughout the entire session. In each session, four independent markets, consisting of five buyers and five sellers in each market, are simultaneously trading. Each buyer and seller is given five (no-tax) infra-marginal units to sell or buy at the beginning of each trading period, and there are 30 trading periods in each of the four markets in a given session. In short, the

[5] A "balanced design" is the discrete-variables analogue of a continuous-variables model in which: (a) the slope of the linear market demand function is the negative of the slope of the linear market supply function; and (b) consumers' surplus equals sellers' surplus at the theoretical competitive equilibrium price and quantity.

experiment uses a between subjects design, with 40 subjects randomly assigned to the role of buyer or seller in equal numbers in each of the four treatments, resulting in a total of 160 subjects.

Table 1 below shows an individual seller's marginal costs and an individual buyer's marginal values per unit. The table shows the five (no-tax) infra-marginal costs and values and the marginal cost and value for a sixth, extra-marginal unit. Each buyer in all four treatments is assigned a value of 50 experimental dollars (ED) for unit 1 of the fictitious commodity, 47 ED for unit 2, 44 ED for unit 3, 41 ED for unit 4, 38 ED for unit 5, and 35 ED for unit 6. These marginal values represent the induced individual demand schedules used in the experiment. Similarly each seller in all four treatments is assigned a cost of 23 ED for unit 1, 26 ED for unit 2, 29 ED for unit 3, 32 ED for unit 4, 35 ED for unit 5, and 38 ED for unit 6. These marginal costs identify the induced individual supply schedules used in the experiment. Costs and values are private information. Throughout each session, the subjects are seated in a manner that protects the privacy of this information. The amount of the unit tax (12 ED) and the assignment of the liability to pay tax are announced to the subjects at the beginning of each session. The costs, values, and tax per unit remain the same throughout each session.

In the absence of a tax, the unique competitive equilibrium quantity is 25 units, consisting of 5 units traded by each buyer and seller. After we impose a unit tax of 12 ED, the unique equilibrium quantity predicted by the theory is 15 units, consisting of 3 units traded by each buyer and seller. The predicted excess burden of this tax is 60 ED [$= 5\times(38 - 35) + 5\times(41 - 32)$].

At the beginning of each experimental session, subjects read through detailed instructions appearing on their computer screens on how to interact with the computer to trade in the market. The instructions for buyers and sellers for all four treatments are available at the following URL:

http://expecon.gsu.edu/jccox/subjects.html. After the subjects read through the instructions, summary instructions are projected on a screen and read to the subjects to help promote understanding of the market participation process. The scripts of the oral summary instructions are available at the URL given above. Subjects are permitted to ask questions of the experimenter, either publically or privately. Before actual trading periods begin, there are five practice trading periods to ensure the subjects are comfortable with the software. These practice periods familiarize the subjects with the software and help them to understand the decision making process. The practice periods are followed by 30 actual trading periods in each session (treatment). The total number of trading periods is not announced to the subjects.

The subjects are mostly undergraduate students at a large urban university in the United States. Table 2 provides information on the demographic profile of the subjects. They are nearly equally divided among class ranks, with 25 percent freshmen, 31 percent sophomores, 20 percent juniors, and 22 percent seniors. Masters students make up only 2 percent of the sample. Approximately 75 percent of the sample has previous experience in an experiment; 59 percent are female; 51 percent are African-American; 20 percent are white; 15 percent are foreign born; and the remaining 14 percent are either Asian-American, Hispanic-American, or mixed race. The average age in our sample is 20 years old; the minimum age is 18; and the maximum age is 24. Approximately 34 percent of the sample is either a business major (accounting, finance, or management) or an economics major. The modal (39 percent) grade point average (GPA) is between 3.25 and 3.74; 9 percent have a GPA between 1.25 and 2.74; 29 percent between 2.75 and 3.24, and 19 percent between 3.75 and 4.0. A small percentage of the sample (4 percent) has yet to receive a final grade in a college course. Although there is some variation in the demographic profiles among the four treatments, the percentages are similar across treatments suggesting that the randomization was successful.

2.1 Induced value information given to subjects

Subjects are given the same information about induced marginal costs and values in every experimental session with either market institution. A seller's trading screen shows "cost per unit" in one column and the "cost plus tax per unit" in an adjacent column.[6] If, however, the buyer is assigned the liability to pay tax, the figures in these two columns are identical, because the unit tax on the seller is equal to zero. Similarly, a buyer's trading screen shows "value per unit" in one column and the "value minus tax per unit" in an adjacent column. If, however, the seller is assigned the liability to pay tax, the figures in these two columns are identical, because the unit tax on the buyer is equal to zero. For further details on the exact layout of the buyer and seller trading screens, the interested reader may see the screen shots in the subject instructions which are available at the URL given above.

2.2 Computerized double auction markets

Two treatments are conducted in DA markets. In one treatment, the liability to pay tax is assigned to the seller in the market and, in the other treatment, to the buyer in the market. The assignment of the liability to pay tax is the only difference in the two DA treatments. The unit tax in both treatments is the same and equal to 12 ED. In both treatments sellers and buyers are given two and a half minutes to complete their transactions in each trading period. The time

[6] For both the double auction and posted offer market treatments, we include separate columns for "cost per unit" and "cost plus tax per unit" in the seller's trading screen and "value per unit" and 'value minus tax per unit' in the buyer's trading screen in order to make the tax salient. Chetty et al. (2009) defines tax salience as the price of a good calculated at the gross-of-tax price. He reports evidence of the impact of tax salience on behavioral responses to taxes from a field experiment and regression analysis using observational data. When taxes are less salient, agents do not optimize relative to the true tax-inclusive prices, and so demand becomes less sensitive to a tax. In other words, a less salient tax makes the own-price elasticity of demand more inelastic relative to a more salient tax, making consumers bear more of the tax burden. Furthermore, Finkelstein (2009) shows that less salient tolls result in more inelastic demand.

remaining in the trading period, the subject's own number of units available to buy or sell, own cumulative earnings, own profit or loss from each traded unit, outstanding bid and ask prices in the market, tax charged per unit, and the market transaction prices are displayed on the trading screens of the buyers and sellers at all times. The bid, ask, and transaction price information provided is a characteristic of the DA market institution.

2.3 Computerized posted offer markets

The remaining two treatments are PO markets. In this market institution, sellers make the first move by posting an offer price and the number of units they are willing to sell at that offer price. Buyers then enter the market in a random queue, one by one, and accept the sellers' offers if they find them attractive. If an offer is accepted, then trade occurs. In one posted offer treatment, the liability to pay a unit tax on each traded unit of a fictitious commodity is assigned to the seller. In the other treatment, the liability to pay a unit tax on each traded unit of the commodity is assigned to the buyer. Again, the assignment of the liability to pay tax is the only difference between these two treatments. In both treatments, sellers have two and a half minutes to post offers to the market in each trading period. Each buyer has an equal amount of time (30 seconds) to accept the available offers in the market. The time remaining to make decisions, own number of units available to buy or sell, own cumulative earnings, own profit or loss from each traded unit, and the unit tax are displayed on the sellers' and buyers' trading screens. A seller's trading screen also lists the offers posted by oneself. Sellers are not able to see the offers posted by other sellers in the market. We believe that this feature of the treatment best reflects the field institution that we are trying to replicate in the laboratory. In the field, knowledge of the prices offered by other sellers in the market can only be obtained through costly surveillance; this information is not provided costlessly by the PO market institution.

A buyer's trading screen lists the number of units available for sale and the offer price corresponding to each of these units as posted by the sellers. For further details on the trading screen's presentation of information and layout, please refer to the screenshots provided in the subject instructions which are available at the URL given above.

2.4 Questionnaire and subject payments

At the end of each session, the subjects are asked to complete a short survey, and then they are paid their cumulative earnings for all 30 trading periods, according to the conversion rate (1 ED = $0.07) announced at the beginning of the session. Table 3 reports the minimum, average, and maximum earnings for each of the 4 treatments. In the DATS treatment, the minimum earnings are $14.25, the average earnings $26.99, and the maximum earnings $38.75. Turning to the DATB treatment, the minimum, average, and maximum earnings are $16.75, $27.66, and $35.25, respectively. In the POTS (POTB) treatment, the minimum earnings are $9.25 ($6.75), the average earnings $20.12 ($20.79), and the maximum earnings $40.75 ($38.50). A session takes approximately 2 hours to complete; thus average earnings exceed $10.00 per hour, which is a favorable hourly earnings rate for student subjects.

3. Data from the experiment

We investigate two questions in this study. Is tax incidence independent of the assignment of liability to pay tax? Is tax incidence independent of the type of market institution? We proceed below by making pairwise comparisons of the average buyer prices from the four treatments. Then, we test the statistical significance of these pairwise comparisons, using the Kolmogorov-Smirnov (K-S) test for two independent samples.[7] We conclude this section with a

[7] If two samples are drawn from the same population, the two cumulative frequency distributions would be expected to be reasonably similar. The test protocol for the K-S test of two independent samples is based on the principle that if there is a significant difference at any point along the two cumulative frequency distributions, the researcher can

discussion of the economic significance of our results by reporting the proportions of total tax revenue paid by buyers and sellers in our four treatments and showing that the excess burdens differ among the four treatments, as well.

There is a lot of "noise" in the prices in the initial trading periods, which no doubt reflects the price discovery process. This noise fades away by the 15th trading period. Prices stabilize more rapidly in the DA markets than in the PO markets, which is consistent with previous findings reported in the literature for experimental markets without taxes. A runs test for serial randomness of the price data from the last 15 trading periods fails to reject the null hypothesis of serial independence in 14 out of the 16 cases at a 10 percent significance level.[8] This provides statistical support for our conclusion based on merely looking at the price series in each trading period that prices have converged to their post-tax equilibrium by the 15th trading period. Consequently, we feel justified in using the data from the last 15 trading periods to calculate the average buyer prices to conduct the analysis.

We make pairwise comparisons of the average buyer prices from the four treatments. According to the theory of tax incidence, there should be no difference between the average buyer prices in the two DA treatments and no difference in the two PO treatments.[9]

Figure 1 shows the percentage differences in pairwise comparisons of average buyer prices from the four treatments. The average buyer price from the DATS treatment is 1.46 percent greater than that from the DATB treatment. Similarly, the average buyer price in the POTS markets is 1.82 percent greater than the average buyer price in the POTB markets. A

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conclude there is a high likelihood the samples come from two different populations. For further details, see Daniel (1990) and Smirnov (1936).

[8] For further details on the runs test of serial randomness, see Zar (1999).

[9] The choice of buyer or seller prices has no bearing on the inferences drawn from the data. The buyer price is the amount paid by a buyer for a unit of the fictitious commodity. The difference between the buyer price and the seller price is always equal to the unit tax or 12 ED. The comparisons among prices *across* the four treatments would be the same if the analysis were conducted in terms of seller prices.

comparison of prices between market institutions reveals that the average buyer price is 5.40 percent higher in the POTS than in the DATS markets, and 5.14 percent higher in the POTB then the DATB markets. Clearly, the differences in average buyer prices are greater for the comparisons between market institutions, holding the assignment of the liability to pay tax the same, than for the comparisons between the assignments of the liability to pay tax, holding the market institution the same. These differences may appear to be rather modest; however, as discussed in greater detail below, relatively small differences in buyer prices lead to much larger differences in excess burdens.

To test the standard theory of tax incidence, we use the K-S test for two independent samples. The K-S statistic is used in a non-parametric test to compare data collected in two different situations. This statistic is robust to alternative distributional properties of the data, non-normal distributions, and heteroskedasticity. Figures 2 through 5 provide pairwise comparisons of the cumulative distribution functions (CDFs) of average buyer prices from pairwise comparisons of the four treatments. Beneath each figure, we report the maximum difference between the two CDFs and the associated p-value of the K-S test statistic. The p-value is the probability of obtaining a test statistic at least as extreme as the one that is actually observed, assuming that the null hypothesis is true that the two samples are drawn from the same probability distribution.

We begin by examining whether the long-run incidence of a tax in competitive markets is independent of the assignment of the liability to pay tax. Figure 2 compares the CDFs of the average buyer prices from the DATB and DATS treatments. These two CDFs appear to be quite different. In fact, the maximum difference between the two CDFs is 0.6167 (p-value = 0.000), which is statistically different from zero. Thus, we can reject the null hypothesis that the two price series come from identical probability distributions. This finding for the DA treatments is inconsistent with the prediction of the standard theory that the incidence of a tax is independent of the assignment of the liability to pay tax.

Figure 3 makes a similar comparison for the two CDFs of the average buyer prices from the PO treatments. Again, the distributions appear to be quite different. The maximum difference between the two CDFs is 0.433 (p-value = 0.000), which is statistically significantly different from zero. Again, this leads us to reject the hypothesis that the incidence of a tax is independent of the assignment of the liability to pay tax in the PO treatments, too.

Now we turn to our second question: Is the incidence of a tax independent of the type of market institution, holding the assignment of the liability to pay tax the same. Figure 4 compares the two CDFs of the average buyer prices from the DATB and POTB treatments. Again the two distributions appear to be quite different, and, indeed, the maximum difference between the two CDFs is 0.9833 (p-value = 0.000), which is statistically significantly different from zero. Finally, Figure 5 compares the two CDFs of the average buyer prices from the DATS and POTS treatments. The maximum difference between these two CDFs is 0.9167 (p-value = 0.000), which is also statistically significantly different from zero.

Although these differences are highly statistically significant, it is important to ascertain whether these differences are economically meaningful. We use several measures of economic significance. We compare the proportions of the total tax revenue paid by buyers and sellers in the four treatments. We also compare the excess burdens created by the tax in each of the four treatments.

Table 4 reports average buyer prices, total tax revenue, and the incidence of the tax as a percent of total revenue for all four treatments for the last 15 periods in each treatment. Since we use a balanced design, the theory of tax incidence predicts that the burden of the tax will be equally shared among buyers and sellers. This is what we observe in the DATB treatment, where approximately 50 percent of the tax burden is borne by buyers and 50 percent by sellers, as shown in the first row of Table 4. Consequently, we use these results to gauge the incidence of the tax in the other three treatments. In the DATS treatment, 55.1 percent of the tax revenue of 180.4 ED is borne by buyers and 44.9 percent by sellers. In contrast, 67.9 percent of the tax revenue of 133.6 ED is borne by buyers and 32.1 percent by sellers in the POTB treatment. The burden of the tax is even further shifted onto buyers in the POTS treatment; here 74.5 percent of the tax revenue of 124.8 ED is borne by buyers and 25.5 percent by sellers. Clearly, these differences in tax incidence among the four treatments are economically meaningful.

Now, we turn to the analysis of excess burdens. Table 5 shows the average quantity, average excess burden, average excess burden as a percentage of tax revenue, and average excess burden as a percentage of participant earnings for the last 15 periods by treatment. The average quantities shown in Table 5 are consistent with the observed differences in tax shifting documented in Table 4. The equilibrium quantity in the DATB treatment is approximately equal to 15 units, which is the post-tax equilibrium quantity predicted by the theory. As a result, the excess burden in the DATB treatment is approximately equal to 60 ED which is the value predicted by the theory. In the DATS treatment, the average quantity is 15.03, and the excess burden is 63.85 ED. In contrast, the average quantities are clearly lower and excess burdens strikingly higher in the POTB and POTS treatments. The average quantities (excess burdens) are 11.13 (134.7 ED) and 10.40 (147.4 ED) in the POTB and POTS treatments, respectively. Table 5 also shows that there are stark differences in excess burdens as a share of tax revenue and as a share of participant earnings among the four treatments.

In short, the data generated by the DATB treatment are consistent with the theory of long-run tax incidence in competitive markets. Using this treatment as the benchmark, we find substantial differences in the average prices and quantities as well as the excess burdens as a share of participant earnings among the other three treatments. Contrary to the predictions of the LSE hypothesis, tax incidence depends on both the assignment of liability to pay tax and the type of market institution in our laboratory experiments.

4. Conclusions

We analyze data from an experiment designed to examine two important questions regarding tax incidence in competitive markets. Is tax incidence independent of: (a) the assignment of the liability to pay tax; and/or (b) the market institution that exists in the taxed market? We use the Kolmogorov-Smirnov (K-S) test for two independent samples to examine the statistical significance of differences in pairwise comparisons of the CDFs of average buyer prices generated by the four experimental treatments in a 2×2 design that crosses selection of buyer or seller tax liability with a double auction or posted offer market institution.

In contrast to the predictions of the theory, we find that the assignment of the liability to pay tax has a statistically and economically significant effect on the long-run incidence of a tax in competitive markets. We also find that a change in the market institution has a greater impact on tax incidence than a change in the assignment of the liability to pay tax. Interestingly, we find evidence of greater tax shifting in the case of the POTS (posted offer institution and tax on sellers) treatment, which is consistent with the econometric evidence of unusual tax-shifting in the analogous field institution. Our results additionally show more tax shifting onto consumers when the assignment of the liability to pay tax is on the seller in both market institutions examined here. Finally, the excess burden created by a unit tax in the DATB (double auction institution and tax on buyers) treatment is consistent with that predicted by the theory of long-run tax incidence in competitive markets.

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Table 1: Individual marginal costs and values per unit

Quantity	Marginal cost	Marginal value
1	23	50
1	26	47
1	29	44
1	32	41
1	35	38
1	38	35

Table 2: Demographic characteristics of the full sample and by treatment

Variable	Sample				
	Full	Double Auction		Posted Offer	
		Tax on seller	Tax on buyer	Tax on seller	Tax on buyer
Percent buyers	50	50	50	50	50
Percent freshmen	25	15	30	30	25
Percent sophomore	31	30	30	30	35
Percent juniors	20	28	10	23	20
Percent seniors	22	25	30	18	15
Percent Masters students	2	3	0	0	5
Percent with experience in experiments	76	78	78	75	73
Percent female	59	55	68	63	50
Percent African-American	51	48	43	58	58
Percent Asian-American	4	3	0	5	8
Percent Hispanic-American	2	5	3	0	0
Percent mixed race	8	10	8	10	5
Percent white	20	23	25	20	13
Percent foreign born	15	13	23	8	18
Average age	20	20	20	20	20
Standard deviation of age	2	2	2	1	1
Minimum age	18	18	18	18	18
Maximum age	24	24	24	24	23
Percent business administration majors	28	25	28	43	18
Percent economics majors	6	0	5	3	15
Percent other majors	0	0	0	0	0
Percent with at least 1 economics course	55	53	58	58	53
GPA between 1.25 and 2.74 (percent)	9	8	5	13	13
GPA between 2.75 and 3.24 (percent)	29	48	28	25	18
GPA between 3.25 and 3.74 (percent)	39	30	35	45	45
GPA between 3.75 and 4.0 (percent)	19	10	30	13	23
Not taken courses with grades (percent)	4	5	3	5	3
Number of experimental subjects	160	40	40	40	40

Table 3: Earnings in U.S. dollars, by treatment

Earnings	Sample				
	Full	Double auction		Posted offer	
		tax on seller	tax on buyer	tax on seller	tax on buyer
Minimum Earnings	$6.75	$14.25	$16.75	$9.25	$6.75
Average Earnings	$23.89	$26.99	$27.66	$20.12	$20.79
Maximum Earnings	$40.75	$38.75	$35.25	$40.75	$38.50

Table 4: Equilibrium buyer prices (ED) and tax burden as a percent of tax revenue, by treatment

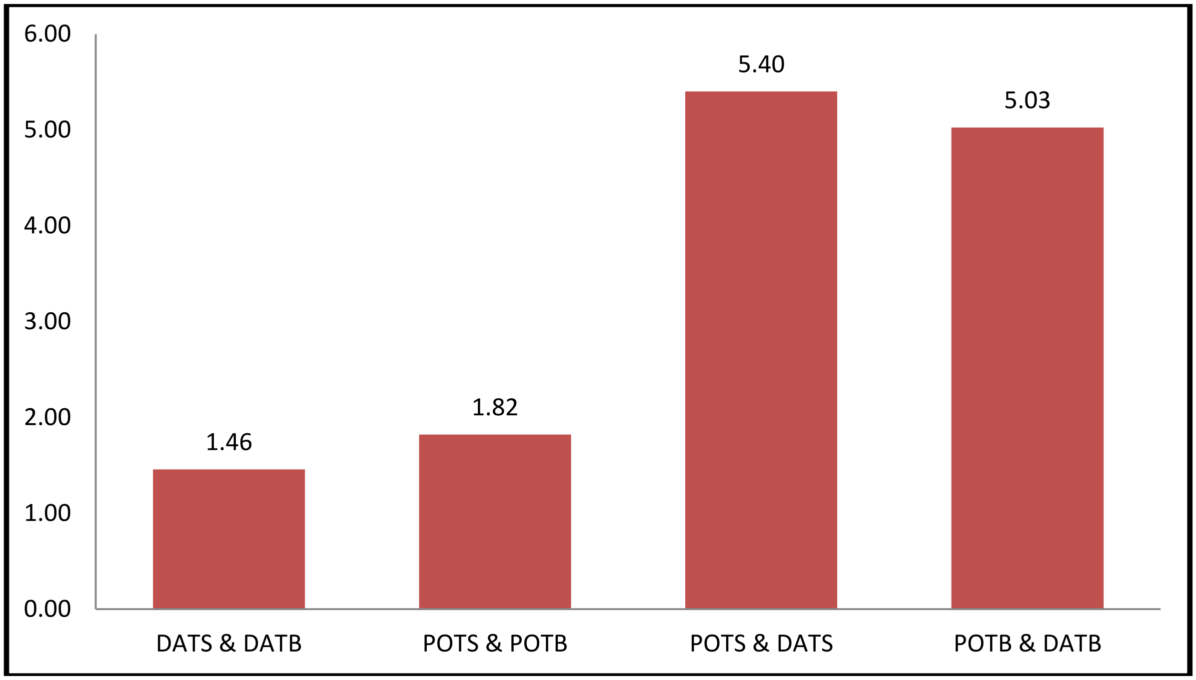
Treatment	Equilibrium buyer price (ED)	Total tax revenue (ED)	Proportion of the tax revenue paid by the buyer (percent)	Proportion of the tax revenue paid by the seller (percent)
Double auction, tax on buyer	41.8	181.2	50.0	50.0
Double auction, tax on seller	42.4	180.4	55.1	44.9
Posted offer, tax on buyer	43.9	133.6	67.9	32.1
Posted offer, tax on seller	44.7	124.8	74.5	25.5

Notes: The estimates reported above are based on the data from the last 15 trading periods of each treatment. The average buyer and seller prices from the DATB treatment are used as the baseline to calculate the incidence of the other three treatments. Figures reported in the table are rounded to first decimal place.

Table 5: Equilibrium quantities and excess burdens, by treatment

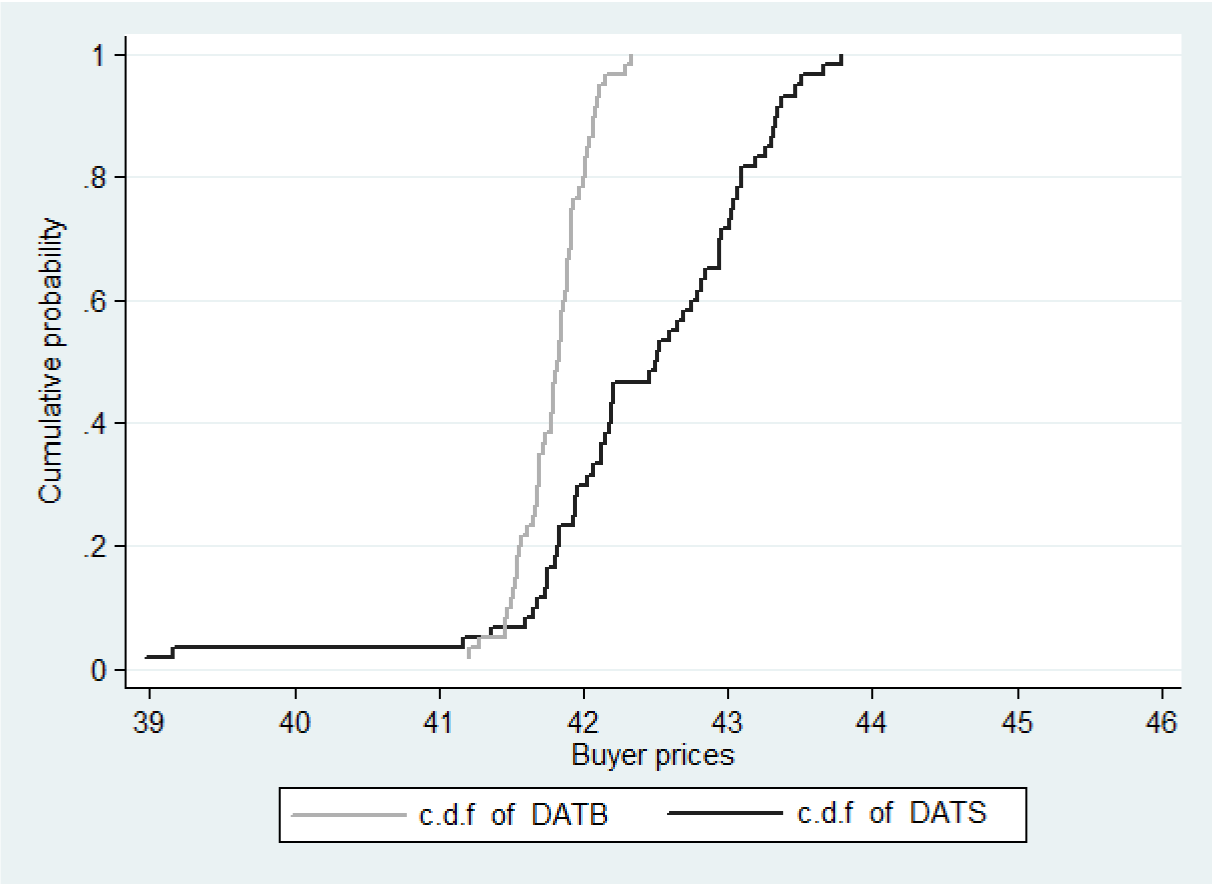
Treatment	Equilibrium quantity (Units)	Excess burden (ED)	Excess burden as a percent of tax revenue	Excess burden as a percent of participant earnings
Double auction, tax on buyer	15.10	60.60	33.44	21.91
Double auction, tax on seller	15.03	63.85	35.39	23.65
Posted offer, tax on buyer	11.13	134.70	100.82	64.78
Posted offer, tax on seller	10.40	147.40	118.11	73.26

Figure 1: Percentage differences in pair-wise comparisons of average buyer prices



Notes: DATB = double auction market with tax on buyer;
DATS = double auction market with tax on seller;
POTB = posted offer market with tax on buyer; and
POTS = posted offer market with tax on seller.

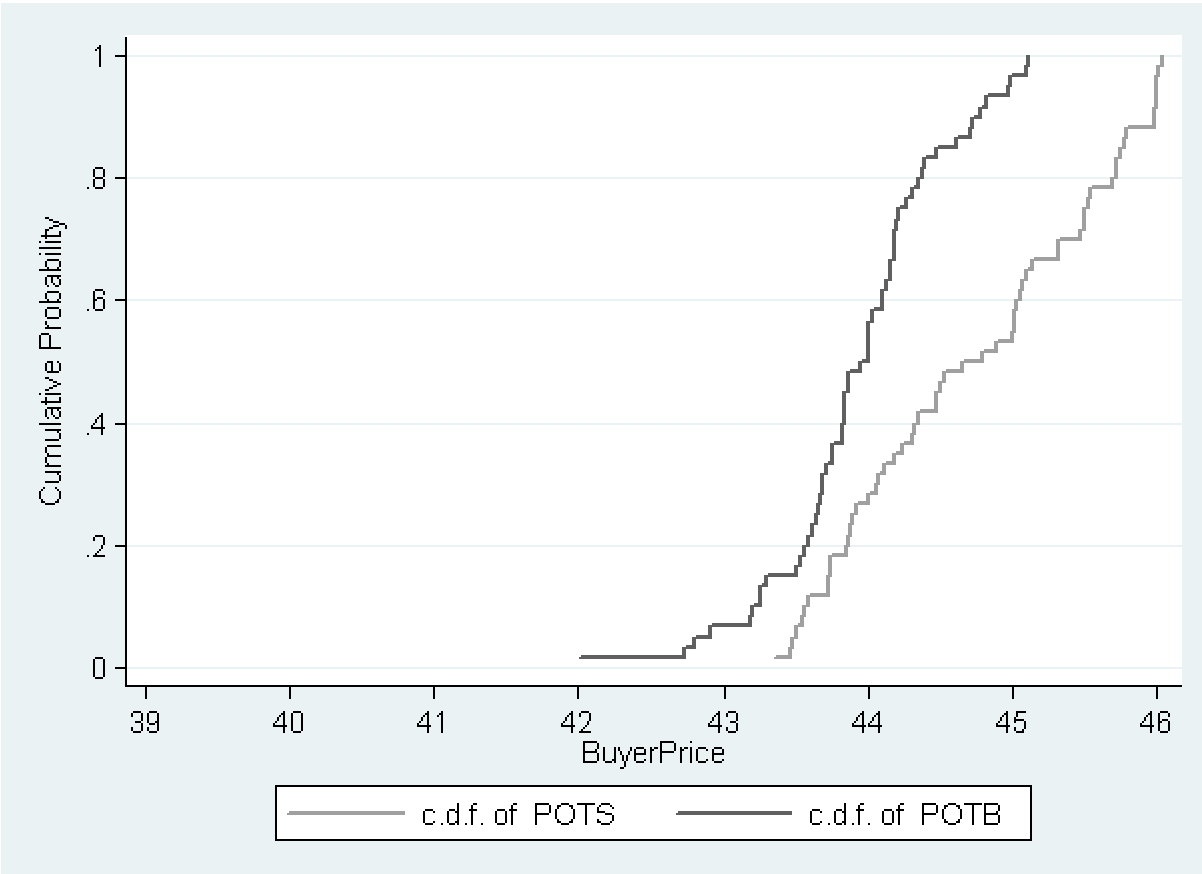
Figure 2: Cumulative distribution functions of the average buyer prices for the two double auction market treatments.



Notes: DATB = double auction market with the tax on the buyer.
DATS = double auction market with the tax on the seller.

Kolmogorov–Smirnov test of the maximum difference between the cumulative distribution functions of the buyer prices of the two double auction market treatments, using the last 15 trading periods. Maximum difference between the two cumulative distribution functions = 0.6167 (p-value = 0.000).

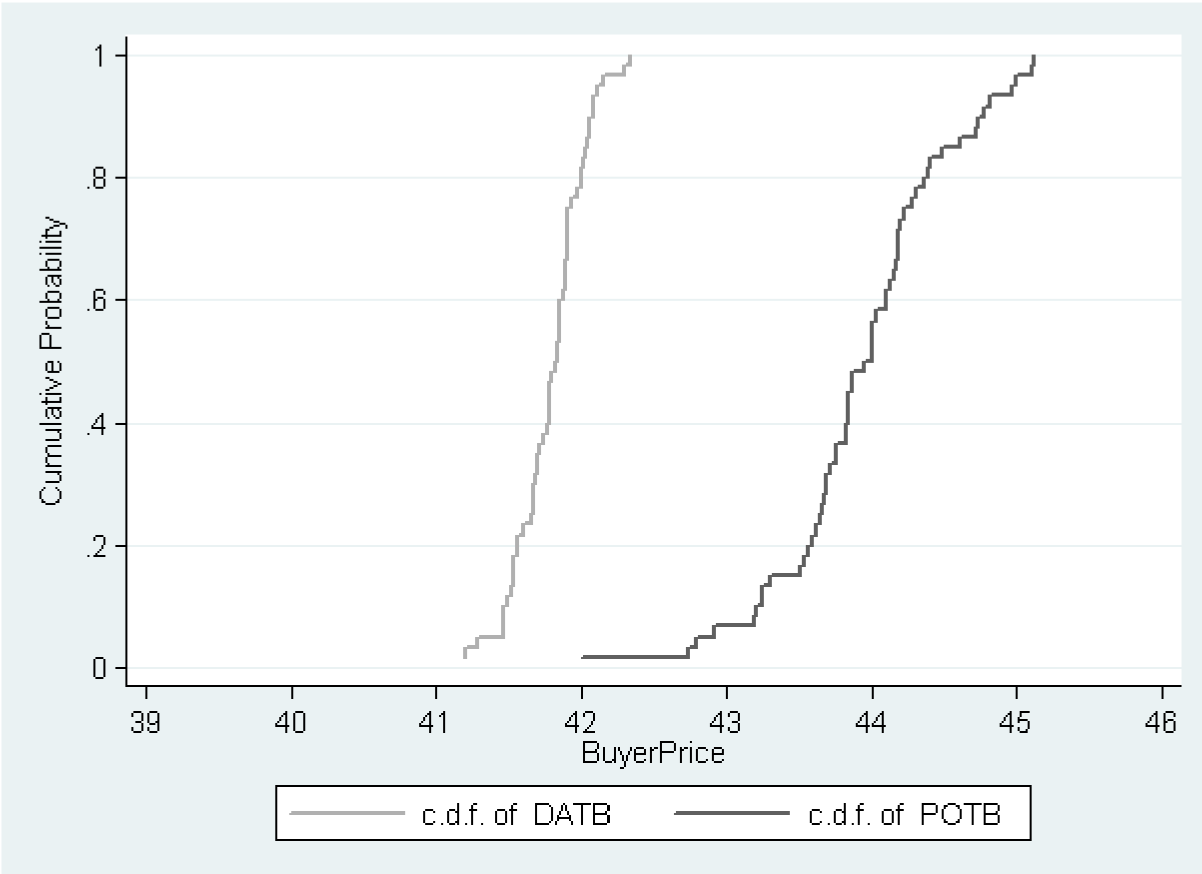
Figure 3: Cumulative distribution functions of the average buyer prices, using the last 15 trading periods of each market session, for the 2 posted offer market treatments.



Notes: POTB = posted offer market with the tax on the buyer.
POTS = posted offer market with the tax on the seller.

Kolmogorov-Smirnov test of the maximum difference between the cumulative distribution functions of the average buyer prices from the two posted offer market treatments, using the last 15 trading periods. Maximum difference between the two cumulative distribution functions = 0.433 (p-value = 0.000).

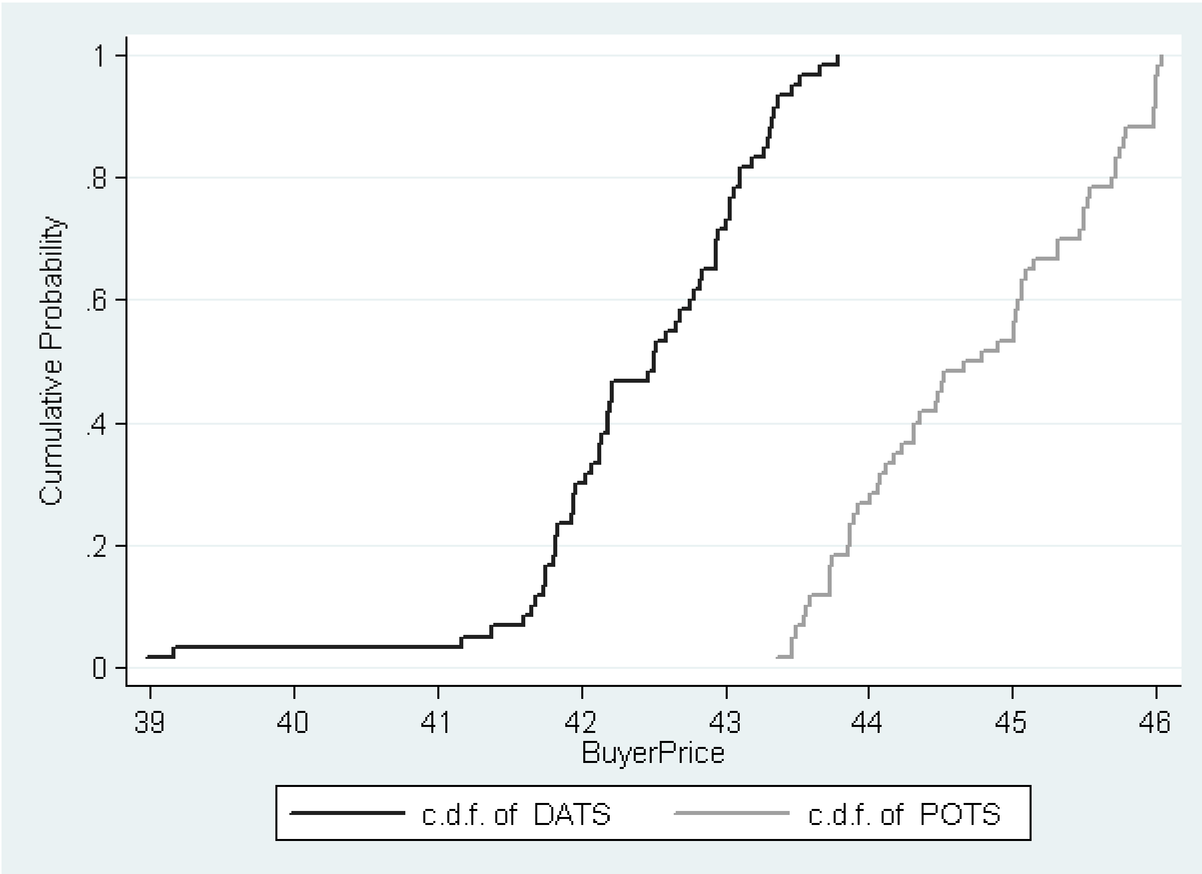
Figure 4: Cumulative distribution functions of the average buyer prices from the double auction and posted offer market treatments with the tax on the buyer.



Notes: DATB = double auction market with the tax on the buyer.
POTB = posted offer market with the tax on the buyer.

Kolmogorov-Smirnov test of the maximum difference between the cumulative distributions of the average buyer prices, using the last 15 trading periods, from the double auction and posted offer markets with the tax on the buyers. Maximum difference between the two cumulative distribution functions = 0.9833 (p-value = 0.000).

Figure 5: Cumulative distribution functions of the average buyer prices for the double auction and posted offer market treatments with the tax on the sellers.



Notes: DATS = double auction market with tax on seller.
POTS = posted offer market with tax on seller.

Kolmogorov-Smirnov test of the maximum difference between the cumulative distribution functions of the buyer prices from double auction and posted offer markets with tax on the sellers, using the last 15 trading periods. Maximum difference between the two cumulative distribution functions = 0.9167 (p-value = 0.000).