EC 331: Research in Applied Economics

The Market for Second-Hand Textbooks at the University of Warwick

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Word Count: 5029
April 2012

Abstract: In the beginning of each academic year the University of Warwick Students' Union creates a posted price market where students can buy and sell second-hand textbooks. We use survey data on the valuation of recommended Economics textbooks to simulate this mechanism and compare it to an alternative – a position auction where buyers bid for the right to purchase a textbook earlier than the others. We find that posted prices are highly inefficient and certain versions of the position auction can generate higher gains from trade. However, this improvement in efficiency is associated with a loss in revenue for the Students' Union.

Acknowledgements: I am grateful to Prof. Peter Hammond for guiding me through numerous methodological issues and for his frequent and valuable feedback. I also wish to thank Dr Jeremy Smith for allowing me to conduct the survey in his lecture and Dr Ganna Pogrebna for sharing her knowledge of level-k models.

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1. Introduction

The recent success of market design has shown that not all market institutions evolve naturally towards efficiency (Roth [2002]). Labour clearinghouses (Roth and Peranson [1999], Niederle and Roth [2009], Coles et al. [2010]), systems of allocating pupils to schools (Abdulkadiroglu, Pathak, and Roth [2009]), as well as monetary markets such as the FCC spectrum auctions (Cramton [1998], Milgrom [2000], Guala [2001]) have been improved using laboratory and computational experiments alongside theory. This paper attempts to apply some of these techniques to a much smaller market but still one that joins hundreds of buyers and sellers – the market for second-hand textbooks at The University of Warwick.

In the beginning of each academic year the University of Warwick Students' Union (SU) creates a marketplace where students are allowed to examine and buy textbooks at posted prices set in advance by sellers. The buyers pay the posted price of their chosen book, while the sellers receive 85% of it. This mechanism produced good results in 2011 when about 2700 of 4000 books were sold[1]. This paper presents a more detailed study of its efficiency and compares it against an alternative mechanism.

Firstly, we simulate the posted price mechanism using survey data on students' valuation of textbooks and the posted prices they would set. As textbooks for the same module are close substitutes, we introduce a unit demand and unit supply framework allowing us to calculate maximum gains from trade by relating to the assignment game introduced by Shapley and Shubik (1972). Secondly, we estimate a level-k rationality model for the behaviour of sellers.

Finally, we analyse an alternative mechanism which has a practical implementation - a position auction in the spirit of Varian (2007) where sellers set prices and buyers

[1] Blog post by George Whitworth on the SU web page:
http://www.warwicksu.com/blogs/blog/georgewhitworth/2011/10/09/Book-Sale-Whats-Left/

simultaneously bid for an earlier place in the queue. Each buyer can choose any book priced below his bid and if he does so, he pays his bid and the corresponding seller receives the price he set plus a fraction of the difference between it and the buyer's bid. We simulate this mechanism using a level-k rationality model fitted with the estimates from the posted price mechanism.

As the SU claims that all revenue from the current book sale is used to cover costs associated with the marketplace, the position auction dominates the current mechanism only if it generates more gains from trade and higher revenue. However, the variations of the position auction we consider do not achieve both goals simultaneously.

Section 2 discusses the literature on efficiency and revenue of posted prices. Section 3 presents the assignment game by Shapley and Shubik (1972) focusing on the linear programming problem of finding maximum gains from trade and an efficient mechanism similar to posted prices. Section 4 describes the survey data. Section 5 discusses the simulations of the posted price mechanism. A level-k model for this mechanism is constructed in Section 6. The position auction is simulated in Section 7. Section 8 concludes.

2. Posted prices in the literature

Posted prices are a widespread method of selling cheap, homogeneous goods, for example in supermarkets. Milgrom (1989, 18) attributes this to the lack of need for buyers to compete, as supply is usually forthcoming. As the market for second-hand textbooks does not possess these characteristics[2] it is natural to doubt the optimality of posted prices.

Mechanism design has shown in numerous settings that posted prices are not revenue-maximising. In Myerson (1981) a monopolistic seller prefers a sealed-bid second-price

[2] Supply does not considerably exceed demand (see Section 4 and Table 2 in Section 5), goods are heterogeneous and relatively expensive.

auction with an inefficient reserve price[3] given symmetric, risk-neutral buyers with independent valuations. McAfee (1993) considers infinite sellers specifying selling mechanisms prior to buyer entry in a multi-period setting. He finds an equilibrium where all sellers hold auctions with an efficient reserve price showing that posted prices are inferior but competition can increase efficiency.

Wang (1993) develops a model of a single seller's decision of whether to auction or sell by posted prices in a dynamic setting with independent private values. If auctions are costly and the valuations of buyers are not sufficiently dispersed, posted prices can be revenue-maximising. Wang (1996) finds the same for correlated private values in a simpler one-shot setting. Campbell and Levin (2006) confirm the result for auctions which are not costly.

Unlike the previous papers, Julien, Kennes and King (2002) consider heterogeneous goods. They find that posted prices are inefficient compared to standard auctions in small markets.

Laboratory experiments have been even more critical of posted prices. Williams (1973) studies a posted price institution with multiple homogeneous goods owned by the sellers. The results show higher prices than those in a competitive equilibrium[4]. Moreover, Ketcham, Smith and Williams (1984) find that convergence to equilibrium can be slower than in the efficiency benchmark - a double auction. As a typical student will only participate in the SU book sale three times or less, the above result indicates that inexperienced agents may be another source of inefficiency. Similarly to the theoretical models, competition between sellers increases efficiency (Coursey, Isaac and Smith [1984]).

Field experiments have primarily focused on data on auctions and posted prices from websites such as eBay. Vakrat and Seidman (1999) find that identical items sell at higher prices in posted price settings compared to auctions and attribute this to search costs and impatience.

[3] A reserve price is the lowest allowed bid.
[4] Many similar experiments confirm these results (Plott [1986]).

Hammond (2008) concludes that the gain in revenue is exactly offset by a lower probability that an item sells. Therefore, it is possible to find a more efficient mechanism than posted prices which provides the same expected revenue.

3. The assignment game

The problem of matching sellers and buyers of textbooks is closely related to the assignment game developed by Shapley and Shubik (1972)[5]. Assume S sellers own one textbook each and B buyers demand one textbook each. Each seller $j \in \{1,..,S\}$ has a lowest price c_j at which he is willing to sell his textbook. Each buyer $i \in \{S+1,..,S+B\}$ has a maximum willingness to pay v_{ij} for textbook j.

A feasible matching μ is a one-to-one correspondence mapping $\{1,..,S+B\}$ onto itself such that if buyer i is matched to seller j, then $\mu(i)=j$ and $\mu(j)=i$. If buyer i is not matched to a seller $\mu(i)=i$ and similarly $\mu(j)=j$ for an unmatched seller j. A vector $(p_1,..,p_S) \in \mathbb{R}_+^S$ contains the prices of all textbooks.

The utility function is linear and additively separable in money and textbooks so if $\mu(i)=j$ buyer i receives a payoff of $u_i = v_{ij} - p_j$ and seller j receives $u_j = p_j - c_j$. An unmatched agent receives 0. The gains from trade between buyer i and seller j are 0 if it is not profitable for them to trade, and $v_{ij} - c_j$ otherwise, denoted by $a_{ij} \equiv max\{0, v_{ij} - c_j\}$.

An optimal matching maximises aggregate gains from trade $\sum_{k=1}^{min\{S,B\}} a_{i_k j_k}$ over all possible permutations of buyers i_1 to i_B and sellers j_1 to j_S. Shapley and Shubik (1972) show that

[5] See Roth and Sotomayor (1990) for a broader exposition of the assignment game and related results.

optimal matchings are also stable (no matched agent prefers to be unmatched and no pair of agents who are not matched to one another prefer to be matched instead). The dual form of the linear programming problem of finding maximum gains from trade is

$$\begin{aligned} &\min_{u_1..u_{S+B}} \sum_{j=1}^{S} u_j + \sum_{i=S+1}^{S+B} u_i \\ &\text{s.t. } u_i \geq 0,\ u_j \geq 0,\ u_i + u_j \geq a_{ij} \ \ \forall i \in \{S+1,..,S+B\}, \forall j \in \{1,..,S\} \end{aligned} \tag{3.1}$$

The value of the objective function at the optimum coincides with the maximum gains from trade because of a fundamental theorem on duality by Dantzig (1963, 129).

Many mechanisms create optimal matchings (Demange and Gale [1985], Demange, Gale and Sotomayor [1986], Sotomayor [2002]). One of them (Perez-Castrillo and Sotomayor [2002]) is also closely related to posted prices. Sellers set prices $p_1,..,p_S$ simultaneously, then buyers act sequentially. The first buyer reports the set of items which maximise his utility at the reported prices. The second buyer reports a set of feasible matchings for him and the first buyer which maximise his utility and assign to the first buyer one of the items he reported. Latter buyers must also honour the preferences of the buyers before them and finally, the mechanism enforces a matching selected by the last buyer. In a dominant strategy subgame-perfect Nash Equilibrium the resulting matching is optimal and the highest price vector compatible with a stable matching is achieved regardless of the order of buyer entry.

There are three differences in SU book sale. Firstly, buyers report one textbook rather than their indifference set. Secondly, transactions are taxed at 15% of the posted prices. Thirdly, information is incomplete. Therefore, if valuations are sufficiently close (so that private information does not distort the strategies) and the former two differences do not affect behaviour significantly, the posted price mechanism might be close to optimal even with incomplete information.

4. The data

The data were collected by distributing a questionnaire during a lecture for the second-year module "Econometrics I" at The University of Warwick, a copy of which is available in Appendix A. The final dataset contains 123 responses out of 362 students taking the module.

Students were asked about their valuations of recommended textbooks for four second-year Economics modules: Macroeconomics II (EC201), Microeconomics II (EC202), Economics II (EC 204), and Econometrics I (EC226). The survey elicits three key prices:

(1) **willingness to pay (WTP) -** the highest price students were willing to pay for each textbook at the start of this academic year provided it was in good (near mint) condition or in bad condition (heavily used).

(2) **posted price -** the price students would set for the textbooks they own at the SU book sale next year. They also reported the condition of the textbooks they own using the same 'good/bad' binary scale.

(3) **willingness to sell (WTS) -** the lowest price, at which students would be willing to sell their textbooks next year at the SU book sale or by other means.

Students are also asked whether they attended the SU book sale in 2011 and what proportion of the textbooks they examined there were in good and bad condition.

We assume throughout the paper that the supply of textbooks is stable over time. This means that the posted prices and WTS reflect the supply conditions at the beginning of this academic year and can be used in conjunction with WTP to describe current supply and demand.

Table 1 presents summary statistics for the valuation of textbooks (standard deviation in brackets). Almost all students expressed an interest in buying second-hand textbooks but only about a third of them attended the book sale (we refer to the latter as buyers). We also limit

our attention to sellers who would consider selling their textbooks at the SU book sale next year (referred to as sellers). It appears that demand exceeds supply but students typically demand only one or two textbooks per module even though they might choose from all of them so demand is overstated.

Very few textbooks were reported in bad condition so the analysis is unlikely to capture a significant heterogeneity factor. Students perceived the quality of the textbooks at the SU book sale very differently: the average estimate was that 58% of textbooks were in good condition but a quarter of the students assessed this figure at 40% or less and another quarter assessed it at 80% or more.

WTP and posted prices tend to be lower for the cheapest textbooks (Dougherty, Gujarati) and higher for the most expensive textbooks (Mishkin, Snyder and Nicholson). Perhaps the quality of a textbook only affects the number of students who demand it, while their actual valuation is proportional to its RRP. Despite the fact that for many textbooks the average buyer would not purchase a copy at the average posted price, trade is likely to occur as there are many buyers with WTP high above the average and many posted prices far below the mean due to high standard deviations (see Figures 1-6). Posted prices are higher than WTS by only about £5 on average which bodes well for efficiency as trade usually breaks down when sellers conceal their values considerably.

The survey investigates control variables which might influence the valuations of textbooks such as course of study, results from the previous academic year, experience in purchasing and selling textbooks via auction websites and national background. However, none of them appear to be correlated with WTP, WTS, and posted prices (see Appendix B). A large number of students (66%) reported having traded textbooks online which is a possible reason for low attendance at the SU book sale.

Table 1. Summary statistics for WTP, WTS and posted prices

Module code	Textbook	RRP (in £)	No. of students demanding a copy of the textbook				Average WTP of buyers		No. of students who own the text-book	No. of sellers for the textbook		Average posted price		Average WTS of sellers	
			in total		at the book sale (buyers)										
			good cond.	bad cond.	good cond.	bad cond.	good cond.	bad cond.		good cond.	bad cond.	good cond.	bad cond.	good cond.	bad cond.
EC201	Blanchard O. "Macroeconomics"	50	96	91	30	28	30.37 (8.5)	17.57 (10.3)	20	16	0	31.56 (5.7)	n/a	25.56 (5.1)	15
EC201	Blanchard O., Amighini A. and Giavazzi F. "Macroeconomics: A european perspective"	50	92	87	27	25	30.67 (7.6)	18.08 (10.4)	19	13	1	27.54 (3.8)	30	22.87 (4.4)	30
EC201	Mishkin, F. "Macroeconomics: Policy and Practice"	53	92	88	30	29	33.03 (8.7)	19.72 (10.3)	24	16	1	32.69 (6.9)	48	22.65 (9.5)	30
EC202 and EC204	Varian H. "Intermediate Microeconomics, A modern approach"	48	104	98	33	31	28.39 (8.9)	16.45 (9.4)	48	30	5	31 (8.5)	29 (10.3)	23.16 (9.6)	21 (4.2)
EC202	Snyder N. and Nicholson W. "Microeconomics Theory: Basic Principles and Extensions"	53	91	86	27	25	33.22 (9.4)	19.92 (11.1)	37	24	2	31.33 (6.8)	20 (14.1)	23.76 (8.5)	10 (14.4)
EC204	Nechyba "Microeconomics, an intuitive approach with calculus"	50	69	65	20	19	30.15 (8.7)	17.16 (9.0)	4	3	0	35 (8.7)	n/a	28.75 (14.4)	n/a
EC226	Wooldridge, J. "Introductory Econometrics: A modern approach"	48	111	105	35	33	30.57 (7.4)	17.42 (9.4)	47	31	1	30.26 (7.2)	30	22.34 (8.6)	20
EC226	Dougherty C. "Introduction to Econometrics"	40	84	78	29	27	24.97 (7.4)	14.89 (8.2)	8	3	1	28.33 (7.6)	10	21 (8.2)	10
EC226	Gujarati D. "Econometrics by example"	40	76	71	25	24	24.20 (6.0)	14.00 (7.4)	7	5	1	25 (7.1)	20	22.6 (7.2)	15
EC226	Stock J. and Watson M. "Introduction to Econometrics"	52	72	68	24	23	29.54 (8.5)	16.87 (8.3)	1	1	0	30	n/a	30	n/a
EC226	Thomas R. "Modern Econometrics"	51	71	67	22	21	29.59 (9.8)	17.00 (9.7)	1	1	0	25	n/a	25	n/a

Figure 1. WTP for the textbook by Blanchard in good condition

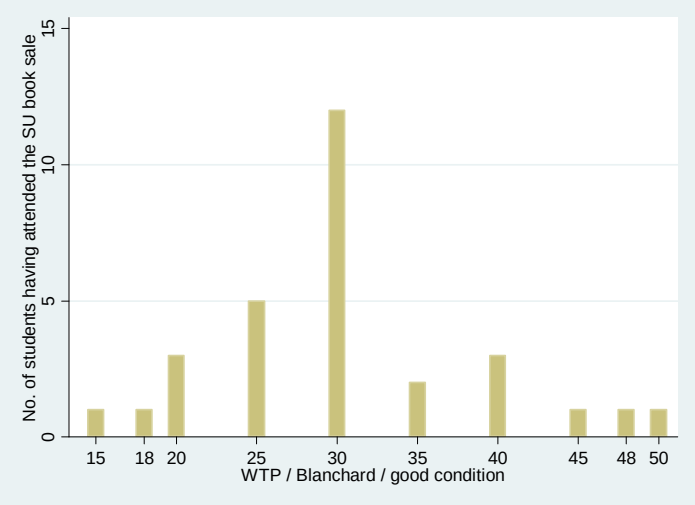


Figure 2. Posted prices for the textbook by Blanchard in good condition

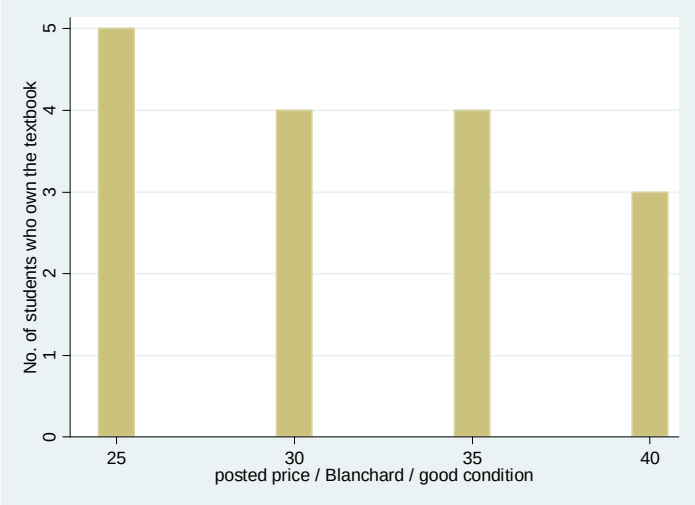


Figure 3. WTP for the textbook by Varian in good condition

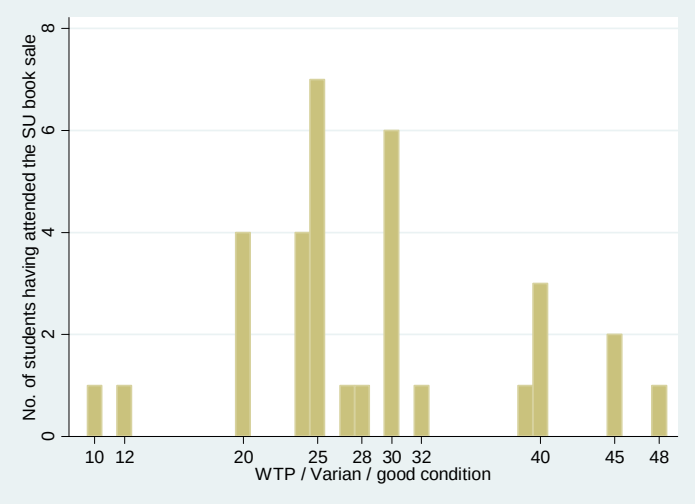


Figure 4. Posted prices for the textbook by Varian in good condition

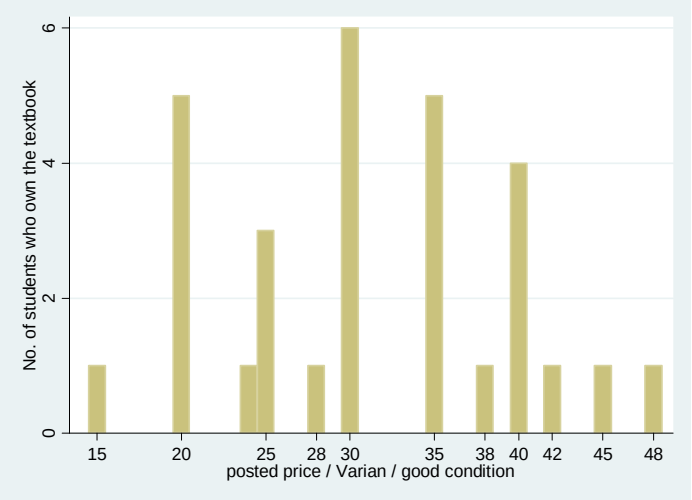


Figure 5. WTP for the textbook by Wooldridge in good condition

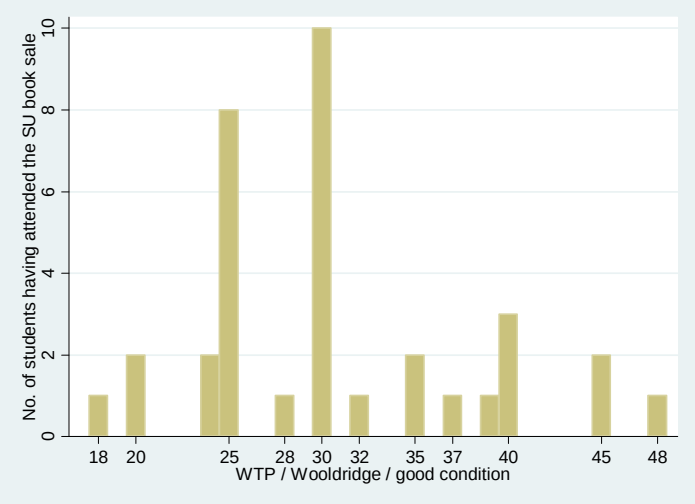
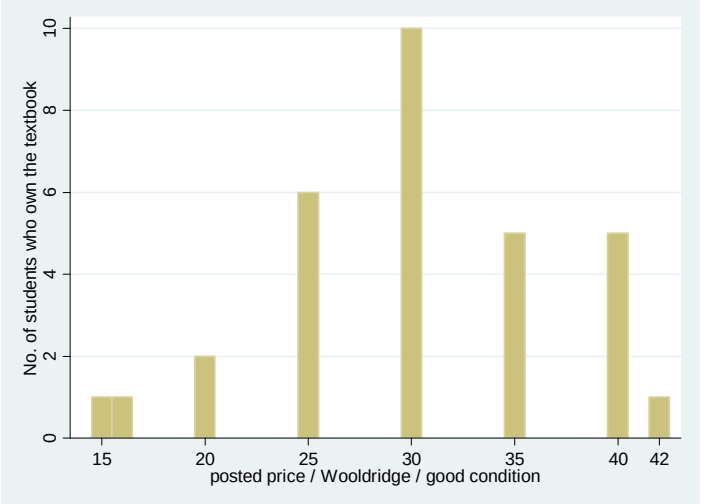


Figure 6. Posted prices for the textbook by Wooldridge in good condition



Finally, the survey asked students whether they would attend the SU book sale next year if it were an auction. 47% of the students responded positively, in comparison to only 31% who attended the book sale this year. Unfortunately, it is unclear whether this rise is owed to the alternative selling method or to an increase in awareness of the SU book sale caused by the survey.

5. Posted price simulations

In the current posted price mechanism sellers set prices for their textbooks unknown to other students and then buyers examine them on a first-come, first-served basis. Buyers pay the posted price of every textbook they purchase and sellers receive 85% of it. This section reports the simulations of this mechanism.

Firstly, we split the SU book sale into separate markets for each module assuming that the decisions of students are independent across modules. Since the textbook by Varian is used in both EC202 and EC204, they are merged into one market for Microeconomics textbooks. The other markets are for textbooks in Econometrics (EC226) and Macroeconomics (EC201).

Within each market we transform the data to create buyers and sellers with unit demand and unit supply respectively. If a seller owns two textbooks, he is split into two sellers each selling one of them. This should not affect the analysis if the pricing decision is independent across textbooks. Moreover, relatively few sellers had two textbooks per module - 7 of 47 in Macroeconomics, 8 of 62 in Microeconomics and 3 of 42 in Econometrics.

There is no certain indicator of whether a buyer demands one or more textbooks for a given module. Since textbooks are close substitutes, we assume that a buyer who owns zero or one module textbook is a unit demand buyer, i.e. even if he expressed interest in buying more than one of the module textbooks, he is content with purchasing just the one which maximises his utility. The rest of the buyers reported having two textbooks and they are split into two unit

demand buyers. The first is only interested in buying one of the textbooks the student reported he owns, and the second wants to buy any one of the remaining textbooks that the student would consider buying.

Using unit demand and unit supply is not necessary though the linear programming problem in Section 3 provides an easy way of computing maximum gains from trade. Moreover, it is difficult to specify preferences over multiple textbooks which are not independent so the unit demand and supply framework avoids the complications of designing a combinatorial auction as an alternative mechanism.

We simulate each of the markets independently with buyers entering in random order. Using the notation from Section 3 to characterise a single market, recall that the utility of buyer i from purchasing textbook j is $u_i = v_{ij} - p_j$ and rearrange the buyers $S+1,..,S+B$ in ascending order of entry. Buyer i chooses a random textbook from his utility-maximising set

$$U_i \equiv \left\{ j \in \{1..S\} \setminus \bigcup_{l=S+1}^{i-1} T_l : v_{ij} - p_j \geq 0,\ v_{ij} - p_j \geq v_{ik} - p_k \ \forall k \in \{1..S\} \right\} \tag{5.1}$$

where T_l is a (possibly empty) set containing the textbook chosen by a previous buyer l. If no textbook gives i positive utility U_i is empty.

Table 2 summarises the results of 1000 simulations. Average gains from trade relative to the theoretical maximum are fairly low in the Macroeconomics and Microeconomics market but high in the Econometrics market where the outcome of the posted price mechanism is very close to the social optimum. However, not all of the gains from trade accrue to students. Subtracting average revenue from the average gains from trade and dividing by the maximum gains from trade yields the students' welfare as a percentage of the maximum. According to

Table 2. Posted price simulations

Market	Number of buyers	Number of sellers	Gains from trade (including revenue)			Average Revenue	Students' average welfare
			Theoretical Maximum	Average	Standard deviation		
Macroeconomics	39	47	413	198	12.6	86	27%
Microeconomics	42	62	580	278	14.4	99	31%
Econometrics	39	42	442	367	9.9	110	58%

this measure, the Econometrics market is about two times more efficient than the other markets, in which students receive less than a third of the maximum gains from trade. This inefficiency can explain the low participation in the SU book sale. It also provides a motivation for designing an alternative mechanism.

6. Level-k rationality model for the posted price mechanism

In order to simulate an alternative mechanism, we specify a common benchmark for behaviour between it and the posted price mechanism – level-k rationality. Level-k models usually fit experimental data better than typical solution concepts such as Bayesian Equilibrium in standard auctions (Crawford and Iriberri [2007]) and in other settings (Stahl and Wilson [1994], Camerer, Ho and Chong [2004]). In this section we create a level-k model for the decision of sellers in the posted price mechanism and the next section uses the estimated levels of rationality across the population to simulate the alternative mechanism.

Consider the Bayesian game representing the posted price mechanism in which WTS is the private value of a seller, WTP is the private value of a buyer and values are independently distributed. We do not extend the realm of private information into other variables because none of them were found to be significantly correlated with the posted prices and WTP (see Appendix B). The model specifies behaviour for level-0 sellers which does not depend on their beliefs of the rationality or values of other agents. Similarly to Crawford and Iriberri (2007) we consider two types: *random* level-0 sellers have an equal probability of choosing any posted price between 0 and the retail price of their textbook and *truthful* level-0 sellers set a posted price equal to their WTS. *Random* and *truthful* level-k sellers believe that other sellers are *random* and *truthful* level-$k-1$ sellers respectively and best-respond to these beliefs. All sellers believe that buyers choose a textbook which maximises their utility, hence the lack of rationality levels among buyers.

Unlike in standard auctions, an explicit solution for the optimal strategies is hard to derive so they are estimated by simulations of the posted price mechanism from the point of view of an "arbitrage seller". Consider a *random* level-1 arbitrage seller in a given market. In each simulation we draw values for all buyers and for $S-1$ *random* level-0 sellers from a distribution whose domain consists of the reported WTP and WTS in the dataset. Each simulated buyer has an equal chance of having the WTP values of each one of the unit demand buyers we created and similarly for the sellers. This assumption is strong but the alternative would be to estimate a distribution of values from the dataset which will be centered on the reported values as well and avoiding this simplifies the simulations tremendously.

In each simulation $t \in \{1,2,..,1000\}$ we denote the highest posted price at which the textbook of the "arbitrage seller" j would sell by hp_{jt}. This is the highest price that a buyer would pay which still makes the textbook utility-maximising for him. The seller believes that if he sets a posted price x, his textbook will sell with probability $p_j(x)$ given by the proportion of simulations in which hp_{jt} was at least x:

$$p_j(x) \equiv \frac{|\{ hp_{jt} : hp_{jt} \geq x,\ t \in \{1,2,..,1000\}\}|}{1000} \tag{6.1}$$

If his book sells, seller j receives 85% of x so his expected utility-maximising posted price $\hat{x}_1^{rand}(c_j)$ solves

$$\max_x EU_j^{1,rand}(x,c_j) = (0.85x - c_j)p_j(x) \tag{6.2}$$

The optimal strategy of a *random* level-2 seller is found by simulating a market with B buyers and $S-1$ *random* level-1 sellers who set posted prices according to (6.2). A similar procedure is used for the *truthful* level-1 and level-2 sellers.

Our model contains *random* and *truthful* level-0, 1 or 2 sellers who follow their optimal strategy but make normally distributed, zero-mean errors. Therefore, the probability that a *random* level-k seller j sets a posted price x_j is given by

$$P_j(x_j \mid k, rand, c_j) = \phi(x_j \mid \hat{x}_k^{rand}(c_j), \sigma_k^{rand}) \tag{6.3}$$

where $\phi(x_j \mid \hat{x}_k^{rand}(c_j), \sigma_k^{rand})$ is the probability density function of a normal variable with mean $\hat{x}_k^{rand}(c_j)$ (the optimal bid) and a type-specific variance σ_k^{rand}. *Random* level-0 sellers are an exception because, by assumption, the probability they set a posted price x_j is

$$P_j(x_j \mid 0, rand, c_j) = \frac{1}{rp_j} \tag{6.4}$$

where rp_j is the retail price of the textbook owned by j.

Let π_k^{rand} and π_k^{truth} be the proportions of *random* and *truthful* level-k sellers. Then the unconditional probability of observing a posted price x_j is

$$L(x_j \mid c_j, \pi, \sigma) = \sum_{k=0}^{2} \pi_k^{rand} P_j(x_j \mid k, rand, c_j) + \pi_k^{truth} P_j(x_j \mid k, truth, c_j) \tag{6.5}$$

where $P_j(x_j \mid k, truth, c_j)$ is defined analogously to $P_j(x_j \mid k, rand, c_j)$,
$\pi \equiv (\pi_0^{rand}, \pi_1^{rand}, \pi_2^{rand}, \pi_0^{truth}, \pi_1^{truth}, \pi_2^{truth})$ and $\sigma \equiv (\sigma_1^{rand}, \sigma_2^{rand}, \sigma_0^{truth}, \sigma_1^{truth}, \sigma_2^{truth})$.

The log-likelihood of observing the whole sample of posted prices for a given module is

$$log\, L(x_1..x_S \mid c_1..c_S, \pi, \sigma) = \sum_{j \in \{1,..,S\}} log\, L(x_j \mid c_j, \pi, \sigma) \tag{6.6}$$

Table 3. Maximum likelihood estimates for the level-k rationality model

	Market		
	Macroeconomics	Microeconomics	Econometrics
π_0^{rand}	0.00	0.00	0.00
π_0^{truth}	0.35	0.24	0.52
π_1^{rand}	0.53	0.68	0.48
π_1^{truth}	0.00	0.08	0.00
π_2^{rand}	0.12	-	-
π_2^{truth}	0.00	-	-
σ_0^{truth}	4.96	0.40	5.10
σ_1^{rand}	4.96	4.33	5.10
σ_1^{truth}	4.96	4.73	5.10
σ_2^{rand}	4.96	-	-
σ_2^{truth}	4.96	-	-

We estimate π and σ by Maximum Likelihood Estimation of (6.6). Table 3 lists the results from the final specifications for each market which involve some restrictions on the parameters (see Appendix C on model selection). Most of the population consists of *truthful* level-0 and *random* level-1 sellers and there are no level-2 sellers, except in the Macroeconomics market. The model has some explanatory power because of the lack of *random* level-0 sellers but it is fairly imprecise as standard deviations are mostly in excess of 4. Despite this, the main results of the paper are robust to repeating the simulations and the estimation of π.

7. Position auction simulations

In this section we simulate a position auction as an alternative to the posted price mechanism. Consider splitting the market into markets for Microeconomics, Macroeconomics and Econometrics textbooks as in the posted price simulations. Every seller sets a reservation price for his textbook, each buyer bids separately for each module and agents are not aware of the actions of others. Buyers are allocated a unique collection time such that higher bids receive the opportunity to purchase a textbook earlier (ties are broken randomly)[6]. They can purchase any textbook with a reservation price below their bid and if they do so, they pay their bid. Sellers receive their reservation price plus a fraction θ of the difference between it and the bid of the buyer who bought it. With regards to buyer participation, we use the students who attended the SU book sale this year for two reasons. Firstly, even though students were asked whether they would participate in an auction next year, there was no control question about their future participation in a posted price mechanism. Secondly, this allows us to compare both mechanisms directly.

[6] In the case of a buyer who wants more than one module textbook he can be allowed to make two separate bids granting him different allocation times. Since the data is transformed into unit demand buyers this is not an issue in the simulations but in practice the opportunity for a second bid may affect strategic behaviour.

To simulate the position auction we use a level-k model similarly to Section 6. Unlike the posted price mechanism, the position auction offers possibilities for strategic behaviour by both buyers and sellers. Each simulation determines the type (*random* or *truthful*) and level of all buyers and sellers randomly according to the population estimates from Table 3. The level-0 behaviour for sellers is the same as in the posted price mechanism, except that they set reservation prices instead of posted prices. A *random* level-0 buyer bids uniformly between 0 and the highest retail price among all module textbooks and a *truthful* level-0 buyer bids his maximum WTP among all textbooks. *Random* and *truthful* level-k buyers and sellers best-respond to the belief that all other agents are *random* and *truthful* level-$k-1$ respectively. The optimal strategies are derived by simulation similarly to Section 6 (see Appendix D).

The position auction dominates posted prices if it generates more gains from trade and at least the same revenue because the SU currently uses all the revenue to cover the costs associated with the marketplace. Table 4 shows that the position auction does not make the Econometrics market more efficient than posted prices for both $\theta = 0.5$ and $\theta = 0$. The other two markets exhibit higher gains from trade when $\theta = 0.5$ but in this case revenue is lower. When $\theta = 0$ revenue is higher in both markets and gains from trade are higher in the Macroeconomics market but slightly lower in the Micreconomics market. Therefore, only the Macroeconomics market benefits from the introduction of a position auction.

Table 5 presents total gains from trade and revenue over all markets. Both position auctions are dominated and we see a clear tradeoff between efficiency and revenue: $\theta = 0.5$ exhibits higher gains from trade but lower revenue and $\theta = 0$ exhibits lower gains from trade and higher revenue in comparison to posted prices. Even if there exists a value of θ between 0 and 0.5 for which the position auction is more preferable, we can expect the improvement to be marginal because of the efficiency-revenue tradeoff. Moreover, the standard deviation of gains from trade over all simulations is considerably higher than in the posted price

Table 4. Position auction and posted prices simulations by market

Market	Mechanism	Gains from trade (including revenue)			Average Revenue
		Maximum	Average	Std. dev.	
Macroeconomics	Posted prices	413	198	12.6	86
Macroeconomics	Position auction $(\theta = 0.5)$	413	263	38.2	65
Macroeconomics	Position auction $(\theta = 0)$	413	245	39.7	126
Microeconomics	Posted prices	580	278	14.4	99
Microeconomics	Position auction $(\theta = 0.5)$	580	330	44.1	66
Microeconomics	Position auction $(\theta = 0)$	580	276	46.2	114
Econometrics	Posted prices	442	367	9.9	110
Econometrics	Position auction $(\theta = 0.5)$	442	320	30.0	107
Econometrics	Position auction $(\theta = 0)$	442	283	37.0	209

Table 5. Total gains from trade and revenue in the position auction and posted prices.

	Total gains from trade	Total Revenue
Posted prices	843	295
Position auction $(\theta = 0.5)$	913	238
Position auction $(\theta = 0)$	804	449

simulations. One reason for this is that a buyer is indifferent between all copies of the textbook he chooses because he pays a constant price so early buyers can bring considerable variation in the simulation outcome.

8. Conclusion

This paper analysed the market for second-hand textbooks at The University of Warwick using survey data on valuations of second-year Economics textbooks. As the literature suggests, the current posted price mechanism was found to be inefficient, though the Econometrics market made an odd exception. High revenue is detrimental to student welfare which, along with the popularity of auction websites, can explain low participation in the SU book sale.

In the design of an alternative mechanism, emphasis was given to simplicity and practical implementation. However, the version of the position auction which can generate higher gains from trade has lower revenue than posted prices. Therefore, the costs of increased welfare fall directly on the SU. One version of the position auction generated more revenue confirming the findings in the literature that a high dispersion of values makes posted prices less desirable for the auctioneer.

Some reservations about the final results need to be expressed because we could neither account for a change in participation in the position auction relative to posted prices, nor for departures from risk-neutrality. Moreover, the binary scale which captured the quality of the textbooks proved to be ambiguous so heterogeneity was not well accounted for. The level-k model for the posted price mechanism was somewhat inaccurate undermining the predictions for the optimal strategies in the position auction which themselves were limited to whole numbers (see Appendix D). Finally, the assumption of independent values is unrealistic because correlation might arise from the common resale price of textbooks.

Appendix A

Survey on the valuation of second-hand Economics textbooks

Answer all questions for a chance to win £15 and to help a fellow student in his research. The survey is confidential and will be used only for research purposes.

For the first four questions, look at the table below. I have listed some textbooks, the module that recommends them and the price at which a new copy of the book can be obtained from the Warwick book shop.

1. In the first pair of columns, write the maximum amount (in pounds) that you were willing to pay for a second-hand copy of the textbooks at the start of this academic year. Please use two numbers – one for your maximum willingness to pay for a book in good (near mint) condition, and one for a book in bad condition (heavily used). If you were not willing to purchase a certain book in a certain condition, write nothing.

2. In the second pair of columns, put a tick (✓) if you own a new or second-hand copy of the textbooks in the box which corresponds to their condition.

3. The Students' Union (SU) organises a book sale in the beginning of each academic year, where sellers set a price for their books and they either sell at this price or not. Would you sell the books you ticked in question 2 at the SU book sale next year? If yes, what price would you set for them (write in column 3)? If you are not willing to sell a particular textbook at the SU book sale, write 0.

4. For the books you ticked in question 2, write the minimum price at which you would be willing to sell them next year in the last column. That is the price which would make you indifferent between selling and keeping the book. If you are not willing to sell a particular textbook, write 0.

Module code[7]	Title	Price	**1**. Maximum willingness to pay		**2**. Do you own the textbook?		**3**. Desired selling price at the SU book sale next year	**4.** Minimum selling price for next year
			Condition		Condition			
			Good	Bad	Good	Bad		
EC201	Blanchard O. "Macroeconomics"	£50						
EC201	Blanchard O., Amighini A. and Giavazzi F. "Macroeconomics: A european perspective"	£50						
EC201	Mishkin, F. "Macroeconomics: Policy and Practice"	£53						
EC202 EC204	Varian H. "Intermediate Microeconomics, A modern approach"	£48						
EC202	Snyder N. and Nicholson W. "Microeconomics Theory: Basic Principles and Extensions"	£53						
EC204	Nechyba "Microeconomics, an intuitive approach with calculus"	£50						
EC226	Wooldridge, J. "Introductory Econometrics: A modern approach"	£48						
EC226	Dougherty C. "Introduction to Econometrics"	£40						
EC226	Gujarati D. "Econometrics by example"	£40						
EC226	Stock J. and Watson M. "Introduction to Econometrics"	£52						
EC226	Thomas R. "Modern Econometrics"	£51						

[7] Module codes correspond to:
EC201 – Macroeconomics II
EC202 – Microeconomics II
EC204 – Economics II
EC226 – Econometrics I

Please turn over to the next page

For the next questions please underline or circle your answer where multiple options are present. Write where applicable.

5. What is your course of study?
L100 Economics
LV13 Economics and Economic History
L116 Economics and Industrial Organisation
LM1D Economics, Politics and International Studies
V7ML Philosophy, Politics and Economics
GL11 Mathematics and Economics
Other (please specify) …….

6. What is your national background?
Home/EU
International

7. What was your average result in the previous year of your degree?
1st
2.1
2.2
3rd or lower

8. Have you used auction websites such as eBay and Amazon to purchase or sell textbooks? Yes / No

9. Have you used auction websites for items other than textbooks? Yes / No

10. Did you attend the Warwick SU book sale this year? Yes / No

11. If you attended the Warwick SU book sale, what proportion of the books you saw were in good (near mint) condition and bad condition (heavily used)?

Good condition …%
Bad condition …%

12. Would you participate in the Warwick SU book sale next year if it was arranged by an auction instead? Yes / No

13. Please write your e-mail if you wish to be included in the prize draw.
……..

Thank you very much for your help!

Appendix B

The survey investigates some factors which might influence the valuations of textbooks such as course of study, results from the previous academic year, experience in purchasing textbooks or other items from auction websites and national background because EU students pay lower fees. The majority (67%) of respondents were on the BSc Economics course and the rest was fairly evenly dispersed between 9 other courses from the Economics department and the Warwick Business School. Figures A1-A3[8] show that WTP, WTS and posted prices for the textbook by Blanchard do not differ for the BSc Economics students compared to others as the cumulative frequencies for both groups are similar. This was confirmed by mean-comparison t-tests[9].

All but four students reported having obtained at least Upper Second Class marks from their previous year of study. There are no significant differences in WTP between students with First Class marks compared to students with Upper Second Class marks or worse (Figure A4). Posted prices and WTS exhibit some difference across academic performance (Figures A5 and A6) but the sample is small and a t-test did not reject the null hypothesis of equal means.

Similar conclusions follow when comparing EU nationals to non-EU students and students who have bought textbooks from online auctions to those without such experience (Figures A7-A12). Therefore, there is no systematic link between the valuation of textbooks and degree course, nationality, academic performance and auction experience. As a consequence, WTS is perhaps the only predictor of posted prices in this dataset.

[8] All figures in this section are limited to the sample of buyers and sellers at the SU book sale, referred to as buyers and sellers in Section 4.
[9] The 5% significance level was used in all statistical tests.

Figure A1. Cumulative frequency of WTP by course.

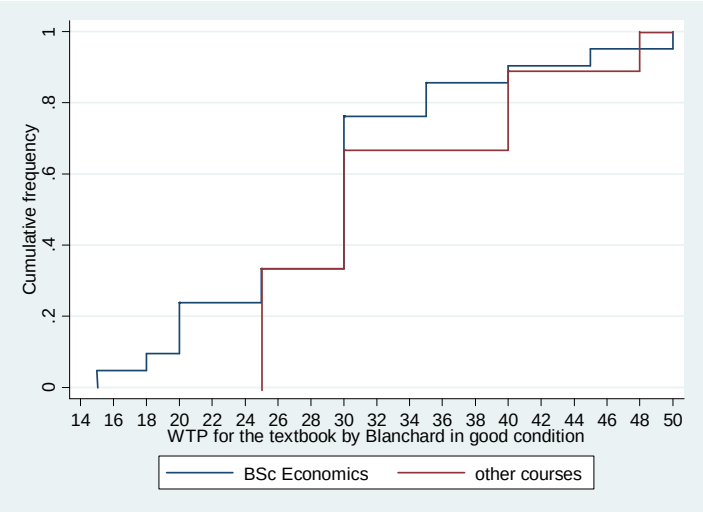


Figure A2. Cumulative frequency of posted prices by course.

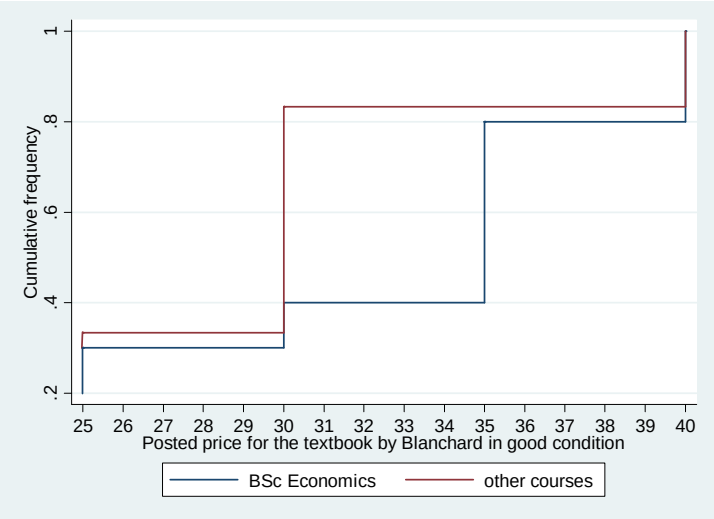


Figure A3. Cumulative frequency of WTS by course.

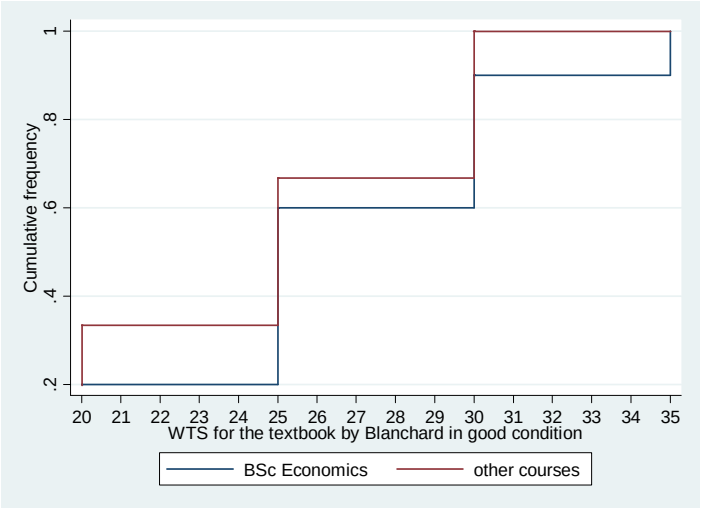


Figure A4. Cum. Freq. of WTP by academic performance.

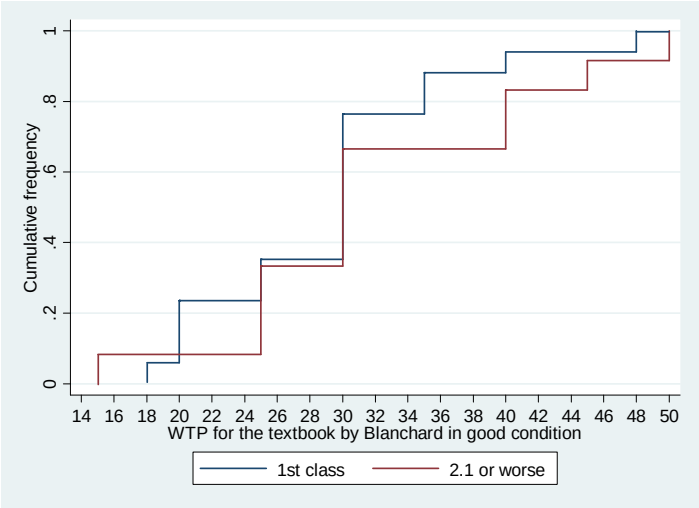


Figure A5. Cum. freq. of WTP by academic performance.

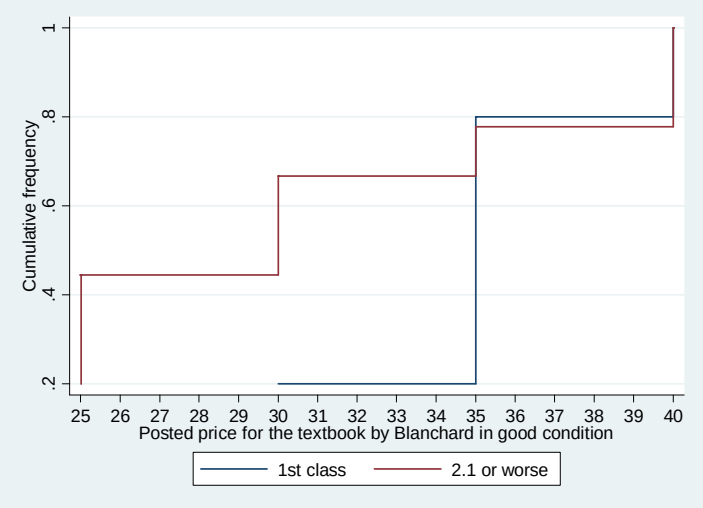


Figure A6. Cum. freq. of WTS by academic performance.

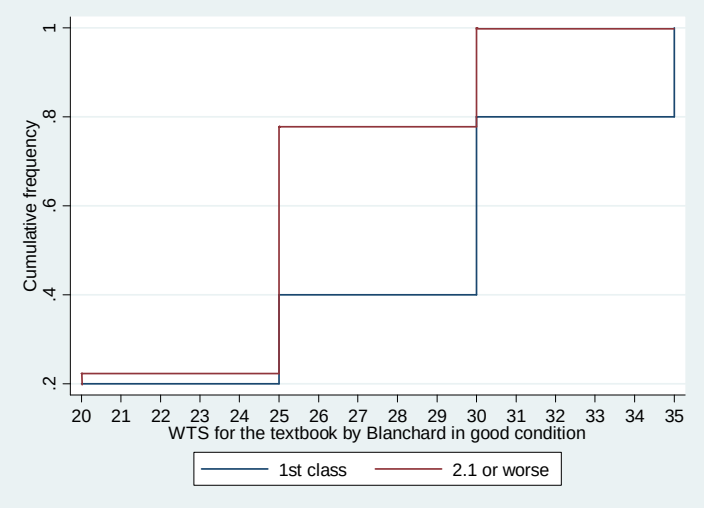


Figure A7. Cumulative frequency of WTP by nationality.

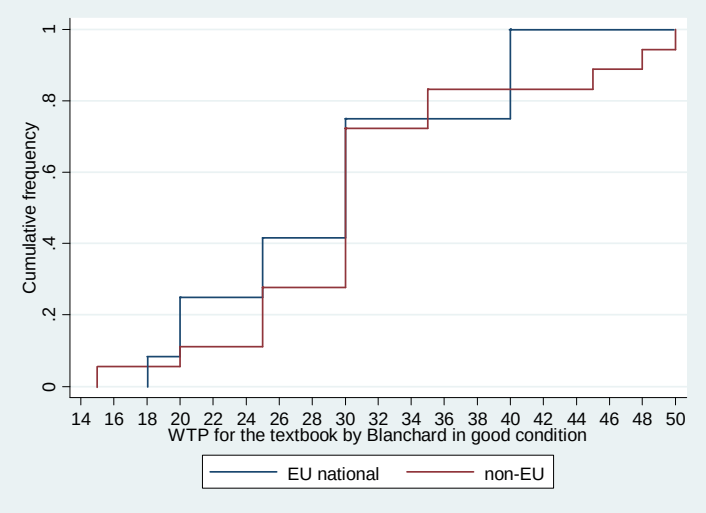


Figure A8. Cum. freq. of posted prices by nationality.

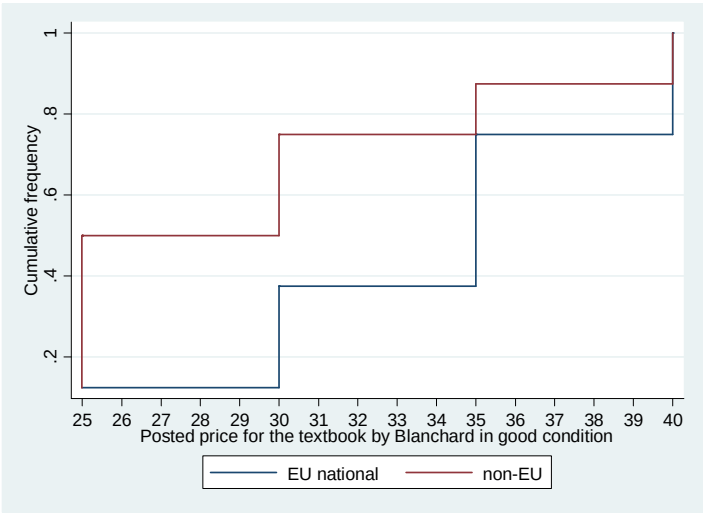


Figure A9. Cumulative frequency of WTS by nationality.

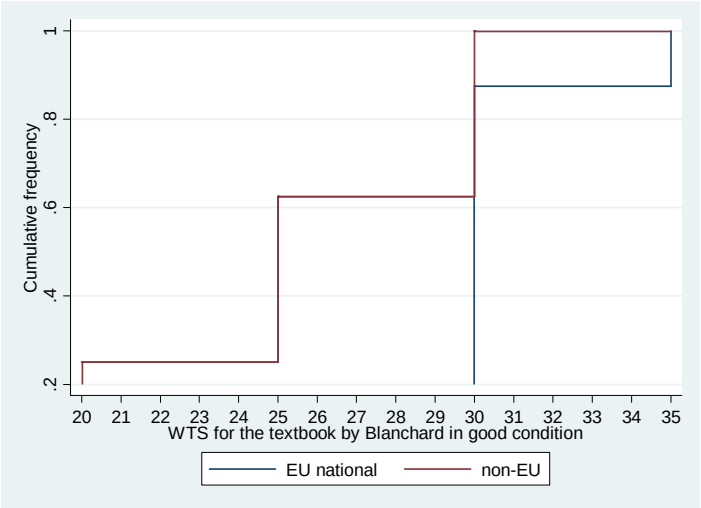


Figure A10. Cum. freq. of WTP by auction experience.

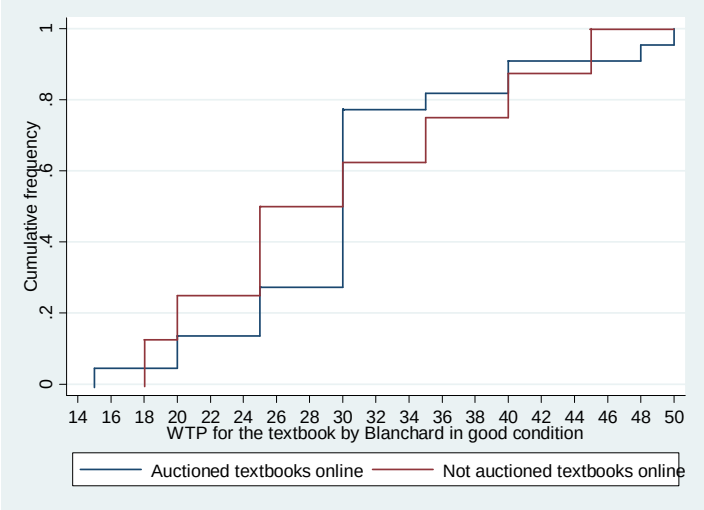


Figure A11. Cum. freq. of posted prices by auction experience.

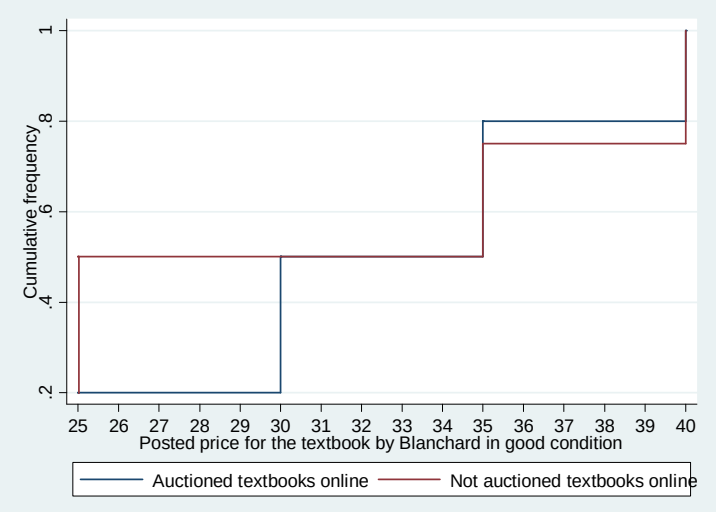
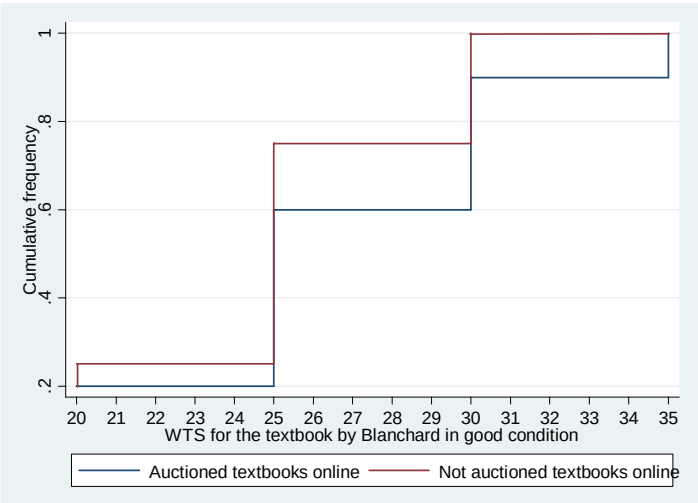


Figure A12. Cum. freq. of WTS by auction experience.



Appendix C

Tables A1, A2 and A3 provide the maximum likelihood estimates from various specifications for each market. The unrestricted specification (6.6) corresponds to all levels and type-specific precision. The restrictions we consider are equal variance for all types $(\sigma_k^{rand} = \sigma_k^{truth} = \sigma)$ and the omission of level 1 or level 2 agents. In all markets, likelihood ratio tests[10] favoured some restricted version of the model. Therefore, the specifications listed in Table 3 in the main body are the most parsimonious specifications which were not rejected, shown in bold in Tables A1, A2 and A3. The Macroeconomics market is a slight exception because a likelihood-ratio test does not reject both a constant precision model without level 1 agents and a constant precision model without level 2 agents over a model with constant precision and all levels. This is because the optimal strategies of "random" level 1 and level 2 agents are very similar and using one instead of the other does not change the likelihood considerably. Since there is no clear favourite among the models omitting level-1 and level-2 agents, the model with all levels was selected despite the existence of a more parsimonious specification.

[10] The test statistic for the likelihood-ratio test is twice the difference in log-likelihood between the unrestricted and restricted models, which is distributed as a chi-squared with degrees of freedom equal to the number of restrictions under the null hypothesis. All conclusions are based on the 5% significance level.

Table A1. MLE estimates for the Macroeconomics market

	Constant precision ($\sigma_k^{rand} = \sigma_k^{truth} = \sigma$)			Type-specific precision		
	All levels	Without level 2	Without level 1	All levels	Without level 2	Without level 1
π_0^{rand}	**0.00**	0.00	0.00	0	0	0
π_0^{truth}	**0.35**	0.34	0.4	0.29	0.29	0.36
π_1^{rand}	**0.53**	0.66	-	0.71	0.71	-
π_1^{truth}	**0.00**	0.00	-	0	0	-
π_2^{rand}	**0.12**	-	0.60	0	-	0.64
π_2^{truth}	**0.00**	-	0.00	0	-	0
σ_0^{truth}	**4.96**	5.03	4.94	3.50	3.50	3.89
σ_1^{rand}	**4.96**	5.03	-	5.44	5.44	-
σ_1^{truth}	**4.96**	5.03	-	5.59	4.46	-
σ_2^{rand}	**4.96**	-	4.94	5.68	-	5.42
σ_2^{truth}	**4.96**	-	4.94	5.62	-	3.93
$log\ L(\cdot)$	**-149.8**	-149.8	-150.4	-148.7	-148.7	-149.7

Table A2. MLE estimates for the Microeconomics market

	Constant precision ($\sigma_k^{rand} = \sigma_k^{truth} = \sigma$)			Type-specific precision		
	All levels	Without level 2	Without level 1	All levels	**Without level 2**	Without level 1
π_0^{rand}	0.00	0.00	0.00	0.00	**0.00**	0.00
π_0^{truth}	0.30	0.30	0.36	0.24	**0.24**	0.24
π_1^{rand}	0.62	0.62	-	0.68	**0.68**	-
π_1^{truth}	0.08	0.08	-	0.08	**0.08**	-
π_2^{rand}	0.00	-	0.60	0.00	**-**	0.76
π_2^{truth}	0.00	-	0.04	0.00	**-**	0.00
σ_0^{truth}	4.41	4.41	5.47	0.40	**0.40**	0.40
σ_1^{rand}	4.41	4.41	-	4.33	**4.33**	-
σ_1^{truth}	4.41	4.41	-	4.73	**4.73**	-
σ_2^{rand}	4.41	-	5.47	6.52	**-**	6.46
σ_2^{truth}	4.41	-	5.47	5.41	**-**	4.35
$log\ L(\cdot)$	-203.6	-203.6	-208.1	-178.4	**-178.4**	-185.0

Table A3. MLE estimates for the Econometrics market

	Constant precision ($\sigma_k^{rand} = \sigma_k^{truth} = \sigma$)			Type-specific precision		
	All levels	**Without level 2**	Without level 1	All levels	Without level 2	Without level 1
π_0^{rand}	0.00	**0.00**	0.72	0	0	0
π_0^{truth}	0.55	**0.52**	0.20	0.48	0.48	0.57
π_1^{rand}	0.34	**0.48**	-	0.52	0.52	-
π_1^{truth}	0.00	**0.00**	-	0	0	-
π_2^{rand}	0.10	-	0.08	0	-	0.43
π_2^{truth}	0.01	-	0	0	-	0
σ_0^{truth}	4.76	**5.10**	0.4	3.90	3.90	4.12
σ_1^{rand}	4.76	**5.10**	-	5.98	5.98	-
σ_1^{truth}	4.76	**5.10**	-	5.36	4.24	-
σ_2^{rand}	4.76	-	0.4	5.50	-	6.10
σ_2^{truth}	4.76	-	0.4	5.29	-	3.77
$log\ L(\cdot)$	-136.7	**-136.8**	-144.8	-135.4	-135.4	-136.4

Appendix D

This section describes how the optimal strategies for the position auction are found.

Consider a *random* level-1 buyer i. The simulations which determine his optimal strategy start by generating $B-1$ *random* level-0 buyers and S *random* level-0 sellers each with the WTP and WTS of one of the unit demand and unit supply agents respectively, as in Section 6. We use the notation from Section 3 adding a t subscript for simulation $t \in \{1,2,..,1000\}$ where necessary. One exception is that p_{jt} is the reservation price set by seller j (not the posted price). Let all buyers $S+1,..,S+B$ in simulation t be ordered by their bids $x_{S+1,\,t},..,x_{S+B,\,t}$ so that $x_{it} \geq x_{kt}$ if $i<k$. We define $L_t(x)=\{j : p_{jt} \leq x\}$ to be the set of all books that can be purchased at price x or less in simulation t. The expected utility i gains from bidding x across all simulations is:

$$EU_i(x)=\sum_{t=1}^{1000} \max_{\substack{j \in L_t(x) \\ j \notin \bigcup_{l=S+1}^{i} T_{lt}}} v_{ij}-x \qquad \text{(A.1)}$$

where T_{lt} is a (possibly empty) set containing the textbook chosen by buyer l in simulation t.

Having bid x in simulation t, buyer i will choose the textbook j that maximises his utility $v_{ij}-x$ equal to his WTP for textbook j less the price he is paying for it, i.e. his bid x. All simulations are implicitly weighted with the same probability. Note that i is restricted to choosing among textbooks that his bid can buy and were not bought by previous buyers.

Given a finite set of possible bids X we can determine the bid $x_i \in X$ which maximises buyer i's utility. We consider whole number bids from 0 to the maximum retail price among the module books, i.e. $X=\{0,1..,\max_j(rp_j)\}$.

To find the optimal strategy of a *random* level-1 seller, we simulate B *random* level-0 buyers and $S-1$ *random* level-0 sellers. Each buyer $i \in \{S+1,..,S+B\}$ chooses a textbook from his utility-maximising set

$$U_{it} \equiv \left\{ j \in \{1..S\} \setminus \bigcup_{l=S+1}^{i-1} T_l : j \in L_t(x_{it}), v_{ij} - x_{it} \geq 0, v_{ij} - x_{it} \geq v_{ik} - x_{it} \ \forall k \in \{1,..,S\} \right\} \quad \text{(A.2)}$$

In words, U_{it} is the set of books which are affordable at a bid of x_{it}, not bought by any of the previous buyers, give buyer i positive utility and maximise it (if no textbook gives him positive utility U_{it} is empty). From the point of view of a seller $j \in U_{it}$, the probability that his textbook is sold to buyer i given that it is priced anywhere below x_{it} is $\frac{1}{|U_{it}|}$ because i is indifferent between all textbooks in U_{it}.

Moreover, there might be textbooks which i would prefer to those in U_{it} but are not available at his bid. If a seller who owns such a textbook were to sell it below x_{it} instead, it would sell with probability 1. The set of these textbooks U_{it}^* is disjoint to U_{it} and is given by

$$U_{it}^* \equiv \left\{ m \in \{1..S\} \setminus \bigcup_{l=S+1}^{i-1} T_l : v_{im} - x_{it} \geq v_{ij} - x_{it} \ \forall j \in U_{it} \right\} \setminus U_{it} \quad \text{(A.3)}$$

Therefore, the (conditional) probability that buyer i chooses the textbook owned by seller j in simulation t provided it is priced below his bid x_{it} and was not chosen by a previous buyer is

$$p_{ijt} = \begin{cases} 0 \text{ if } j \notin U_{it}, j \notin U_{it}^* \\ \frac{1}{|U_{it}|} \text{ if } j \in U_{it} \\ 1 \text{ if } j \in U_{it}^* \end{cases} \quad \text{(A.4)}$$

We can also define the cumulative probability that the textbook owned by j is sold to buyer i or a buyer before him in simulation t provided it is priced below x_{it} by $\tilde{p}_{ijt} = 1 - \prod_{k=S+1}^{i} (1 - p_{kjt})$. If we consider any reservation price y instead we can define the same cumulative probability by $\tilde{p}_{ijt}(y) = 1 - \prod_{\substack{k=S+1 \\ x_k \geq y}}^{i} (1 - p_{kjt})$ where the additional condition comes from the fact that a buyer changes the cumulative probability only if he can afford the textbook priced at y. Using this, we can define the unconditional probability that the textbook owned by j is sold to buyer i given its reservation price of y_j by

$$\hat{p}_{ijt}(y_j) = \begin{cases} \tilde{p}_{ijt}(y_j) \text{ if } i = S+1 \\ \tilde{p}_{ijt}(y_j) - \tilde{p}_{i-1,\,jt}(y_j) \text{ otherwise} \end{cases} \tag{A.5}$$

Therefore, the expected payoff of seller j who sets a reservation price of y_j over all simulations is

$$EU_j(y) = \sum_{t=1}^{1000} \sum_{i=S+1}^{S+B} \hat{p}_{ijt}(y + \theta(x_{it} - y) - c_j) \tag{A.6}$$

Recall that θ is the fraction of the difference $(x_{it} - y)$ between the buyer's bid and the reservation price which accrues to the seller so the price seller j obtains from a transaction with i in simulation t is $y + \theta(x_{it} - y)$ and subtracting his WTS c_j gives his utility.

Given a finite set of possible reservation prices $Y_j = \{1, 2..rp_j\}$ we can find $y_j \in Y_j$ such that the expected utility of the seller $EU_j(y)$ is maximised giving us the optimal strategy of a *random* level-1 seller. We can find the optimal strategy of *random* level-2 buyers and sellers by simulating buyers and sellers who play the optimal strategies we derived above. Optimal strategies for *truthful* buyers and sellers are found in the same manner.

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