APPENDIX TO "THE NATURE OF EXCESS: USING RANDOMIZATION TO UNDERSTAND HOW MARKETS EQUILIBRATE"

Omar Al-Ubaydli, John A. List, Ariel A. Listo and Michael K. Price

March 2021

ANALYSIS OF THE ORIGINAL DATA IN SMITH (1965)

As Smith himself noted, one cannot get too close to the equilibrium price p^* as the excess supply model suffers from a floor effect. Importantly, this floor effect implies that if identifying variation in p_{t-1} occurs in the range $p_{t-1} \in [p^*, p^* + \chi]$, the Walrasian and excess rent models are indistinguishable. Naturally, if χ is known, then one need only avoid the region $[p^*, p^* + \chi]$. Unfortunately, there are no grounds for reliably specifying χ. Smith assumed that $\chi \leq \$0.05 = 0.045(v - c)$ and showed that his results were unaffected by dropping data points in the relevant range. Unfortunately, his results are not robust to assuming a larger value of χ. To see this, we reconstruct Smith's original data.

Table A1 is a reproduction of *Table 2* from Smith (1965) while Table A2 is our attempted reconstruction of Smith's results. In reconstructing the data, we relied upon Smith's Figures 1A-1F each of which show the sequence of trades (and the associated trade price) for a given experimental session. In principle, the information contained in the figures should have allowed us to recover all of his data. However, the grid has imperfections and we were unable to perfectly replicate his dataset.

Table A1: Table 2 from Smith (1965)

Model	1	2	3	4	5	6
Excess rent	-0.023***	-0.021***	-	-0.021***	-0.019***	-
Standard error	(0.005)	(0.005)	-	(0.007)	(0.006)	-
Excess supply	0.220	-	0.026	0.152	-	-0.255
Standard error	(0.195)	-	(0.197)	(0.299)	-	(0.268)
Constant	-0.613	0.342	-1.332	-0.682	-0.200	-0.952
Standard error	(1.108)	(0.597)	(0.507)	(1.307)	(0.892)	(1.327)
% of tunnel dropped	None	None	None	4.5%	4.5%	4.5%
Observations	259	259	259	189	189	189

The dependent variable in all regressions is Δp_t. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).

Table A2: Attempted reconstruction of Table 1 using data inferred from charts

Model	1	2	3	4	5	6
Excess rent	-0.023***	-0.022***	-	-0.021***	-0.019***	-
Standard error	(0.005)	(0.005)	-	(0.007)	(0.006)	-
Excess supply	0.225	-	0.025	0.152	-	-0.255
Standard error	(0.198)	-	(0.200)	(0.299)	-	(0.268)
Constant	-0.603	0.373	-1.326	-0.682	-0.200	-0.952
Standard error	(1.048)	(0.601)	(1.074)	(1.307)	(0.892)	(1.327)
% of tunnel dropped	None	None	None	4.5%	4.5%	4.5%
Observations	259	259	259	191	191	191
R^2	0.074	0.069	0.000	0.046	0.044	0.005

The dependent variable in all regressions is Δp_t. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).

Nevertheless, as noted in Table A2, we are able to achieve a high degree of accuracy with our recovered data. There are few discernible differences in the estimated coefficients across Smith's original analysis and our reconstruction – particularly if we restrict attention to the terms capturing the effect of excess rents and excess supply. For example, across all specifications, the estimated coefficient on excess rents (excess supply) is within 0.001 (0.008) of those reported in Smith (1965).

Table A3: Extended results using data recovered from Smith (1965)

Model	1	2	3	4	5	6	7	8
Excess rent	-0.034	-0.026**	-0.019	-0.022	-0.019	-0.229**	-0.030	-0.005
Standard error	(0.025)	(0.012)	(0.021)	(0.013)	(0.012)	(0.092)	(0.040)	(0.054)
Excess supply	0.497	-	-	-	-	-	-	-
Standard error	(1.241)	-	-	-	-	-	-	-
Constant	0.998	1.423	-0.300	-0.175	0.454	18.778**	1.660	-4.109
Standard error	(2.781)	(2.555)	(1.198)	(2.277)	(2.478)	(7.95)	(10.142)	(18.393)
% of tunnel dropped	25%	25%	4.5%	4.5%	4.5%	25%	25%	25%
Excess supply	Pooled	Pooled	2	5	8	2	5	8
Observations	70	70	89	56	46	33	24	13
R^2	0.066	0.064	0.009	0.048	0.048	0.165	0.025	0.001

The dependent variable in all regressions is Δp_t. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).

Table A3 extends the models that Smith estimated to account for the concerns noted above.[1] In models 1 and 2, we increase the price floor from 4.5% of the trading tunnel's height from the equilibrium price to 25% of this value. As noted in the Table, Smith's conclusions are not robust to this change in the assumed value of χ. In one of the two specifications, the parameter estimate for the measure of excess rent loses its statistical significance.

The support for the excess rent model is further eroded once we condition the analysis on the underlying excess supply system and allow for heterogeneous treatment effects. Models 3-5 in Table A3 replicate model 5 in Table A1 but condition the analysis on the underlying constant excess system. Models 6-8 in the table impose a more stringent price floor – we drop any trades that fall in the bottom quartile of the trading tunnel.

Empirical results from these models call into question Smith's assumption of a homogenous treatment effect. For example, as noted in Models 6 and 7, a $1 increase in excess rents leads to an approximate $0.23 reduction in price for a system with excess supply of two units – an effect that is more than seven-fold that estimated for a system with an excess supply of five units. Perhaps more importantly, however, only one of the six regressions yields a significant coefficient on excess rent. Taken jointly, our reassessment calls into question Smith's interpretation of the data and the robustness of his results.

Notably, the homogeneous treatment effect assumption is actually much stronger than just described. A demand and supply system is defined by the values/costs of its participants. Every time a pair of traders strikes a deal and exits the market, the system has changed as there are now two fewer traders. The change is unlikely to be appreciable in markets with hundreds or thousands of traders. However, in a market with below 30 traders, the two traders exiting represent anywhere from 7%-33% of the market.[2] Given the importance of the Walrasian model for the design of dynamic auctions and matching markets where the number of participants is likely to be small, this is an important consideration that has been overlooked in the extant literature.

Moreover, in non-constant excess systems, where sellers and buyers are not homogenous, the shapes of the supply and demand schedules can change substantially after a pair trade and exit. Smith (1965) and the subsequent literature assume a treatment effect that does not vary with respect to the system by pooling data. Smith did not collect enough data for us to explore if this assumption affects his results.

In conclusion, our retrospective analysis calls into question Smith's (1965) received results and casts doubt on whether the excess rent model is an appropriate depiction of price adjustments.

[1] Smith (1965) did not use clustered standard errors. To maintain comparability in Table A3, neither do we, though using them does not affect our results.

[2] Smith's constant excess experiments had 11 buyers and either 13, 16 or 19 sellers. See Alton and Plott (2007, 2008) for pioneering ways of modeling a continuous in- and out-flow of traders.

RANDOMIZED PRICE INDUCEMENT TECHNIQUE – DISCUSSION

Alternative inducement techniques than our prevailing announcement exist. One is to delay such a statement until a certain amount of trading time has elapsed. A second is to introduce confederates who are instructed to trade at a pre-arranged price and time. We rejected both options for the same reasons. First, piloting indicated that the first trade would occur very quickly (often within less than 20 seconds). Second, in a Chamberlin market, the intensity of negotiations meant that subjects were often not paying attention to the monitor's statements during the trading round. This would serve to add noise to the effect of the inducement and thus reduce statistical power.

Another alternative is to use random price controls that prevent traders from trading within a certain range of prices, such as those deployed by Crockett et al. (2011). For their study, this method served its purpose well, as they aimed for exogenous trades within a certain range. However, for the purposes of comparing the excess supply and excess rent models, our method adds an important dimension: it enhances the information that is conveyed by the announcement.

We believe that making a price announcement about a trade occurring in a similar market is a good simulation of the information content usually transmitted through the observation of naturally-occurring prevailing prices. Since the prevailing price gives traders a lower (upper) bound on the value (cost) of at least one trader, they can look at their values/costs and make an inference about their standing compared to the market. This process is essential to the described mechanics of the excess rent model, and therefore it is an important inclusion for its testing. In fact, the alleged superiority of markets to central planning rests on the ability of the prevailing price to transmit relevant information about the state of the market. In contrast, if one were to use purely price controls that were unrelated to any previous market activity, traders learn nothing immediately and must wait to start trading before they can learn something about their standing compared to the remaining traders.

In support of this view, we draw upon a sizeable literature in the neurosciences arguing that people learn not only from their own actions/experiences but also from the experiences of others who have completed similar tasks (Lohrenz et al. 2007, Hayden et al. 2009, Burke et al. 2010). In particular, this literature highlights that observing the actions and outcomes of others triggers activity in the same region of the brain that is active when processing information about one's own actions and experiences. On a neural basis, the actions of others provide a close (if not perfect) substitute for one's own experience.

Moreover, in both instances, individuals have been shown to engage in fictive or counterfactual learning whereby actions are evaluated based on the difference between actual rewards and those that would have been experienced if another action had been taken. For purposes of our method of price inducement, this is a crucial point. Observing prices generated in a similar market should trigger the type of thinking and subsequent adjustments underlying the excess rent and excess supply models.

EXPERIMENTAL INSTRUCTIONS

Today, we are going to set up a market in which some of you will be buyers and some of you will be sellers. The commodity to be traded is divided into distinct items, or "units". We will not specify a name for the commodity; we will simply refer to units.

Trading will occur in a sequence of trading rounds. The prices that you negotiate in each round will determine your earnings. You will be paid all earnings for the session at the end of the session in cash.

The experiment will consist of 6 rounds. The first 2 rounds will be practice and will not affect your earnings for the experiment.

Every round, you will get a card. The card will indicate whether you are a buyer or a seller for that round. During the practice rounds, you will be both a buyer and a seller. Once we have completed the practice rounds, you will be assigned the role of either a buyer or a seller and will remain in that role throughout the remainder of the session.

Prior to the start of each round, sellers will be provided a seller's card. The number on the sellers' card is known as their "cost". Your cost represents the minimum amount for which you can sell a unit. This information contained on the seller's card is strictly private. A seller's costs may change each round.

Sellers earn money by selling units at prices that are above their cost. Earnings from the sale of each unit are the difference between the sale price and the cost. For example, if a seller has a cost of $10 and sells their unit for $15, they earn $15 – $10 = $5.

If a seller does not sell their unit, they earn exactly zero that round. You will only be allowed to sell at a price equal to or greater than your cost. If you attempt to sell a unit at a price that is less than your cost, your trade will be cancelled.

Prior to the start of each round, buyers will be provided a buyer's card. The number on the buyers' card is known as their "value". Your value represents the maximum amount for which you can purchase a unit. The information contained on the buyer's card is strictly private and a buyer's value may change each round.

Buyers earn money by buying units at prices that are below their value. Earnings from the purchase of each unit are the difference between the value and the purchase price. For example, if a buyer has a value of $20 and buys a unit for $12, they earn $20 – $12 = $8.

If a buyer does not buy a unit, they earn exactly zero that round. You will only be allowed to buy at a price equal to or below your value. If you violate attempt to purchase a unit at a price that is greater than your value, your trade will be cancelled.

In addition to earnings from buying (selling) at a price that is less than your value (greater than your cost), we will provide a commission of 25¢ to both the buyer and seller for each unit traded.

[Chamberlin markets]

Each trading round will be up to 3 minutes long. During the round, you can approach anyone to negotiate a potential sale/purchase. There are three rules that you must follow during the experiment.

1. You are not allowed to threaten or intimidate other traders.
2. You are not allowed to discuss or disclose your cost or value with any other trader.
3. You are not allowed to discuss post-session side payments with any other trader.

If you violate any of these rules, you will be asked to leave the experiment and will earn nothing for participating.

If you make a trade, you and your partner should approach me immediately and inform me of the trade price to confirm that it is a legitimate trade. Remember that you cannot trade in a way that gives you negative earnings. That means sellers can only trade at a price above their cost and buyers can only trade at a price below their value.

After any pair trade and I have a record of their trade price, I will call out their trade price so that all the remaining participants can hear it.

I will now hand out practice trading cards. Remember: you are not allowed to discuss the information on the cards with any other trader. Please take care not to reveal it accidentally to curious traders looking over your shoulder.

[DOA]

Each trading round will be up to 3 minutes long. Once the market is open, any buyer is free to raise their hand and, when called upon, make a verbal bid to buy at a price that is less than or equal to their value. Likewise, any seller is free at any time to raise their hand and, when called upon, to make a verbal offer to sell at a price that is equal to or above their cost. I will record bids and offers on this board. Any seller is free to accept the bid of any buyer, and any buyer is free to accept the offer of any seller. As soon as a bid or offer is accepted, a binding contract has been closed and the buyer and seller making the deal are to drop out of the market, making no more bids, offers, or contracts for the remainder of that trading period.

Note that buyers cannot withdraw bids and sellers cannot withdraw offers. However, after a trade has been completed, I will erase all standing bids and offers from the board.

Except for the bids and offers you are not to speak to any other subject until the experiment is complete. If you violate this rule, you will be asked to leave the experiment and will earn nothing for participating.

If you make a trade, I will confirm that it is a legitimate trade. Remember that you cannot trade in a way that gives you negative earnings. That means sellers can only trade at a price above their cost and buyers can only trade at a price below their value.

After any pair trade and I have a record of their trade price, I will call out their trade price so that all the remaining participants can hear it.

I will now hand out practice trading cards. Remember: you are not allowed to discuss the information on the cards with any other trader. Please take care not to reveal it accidentally to curious traders looking over your shoulder.

We will now do 2 practice rounds. For the practice rounds, earnings will be denominated in $. Earnings from these rounds do not count towards your total earnings for today's session. Rather the practice rounds are designed to provide you familiarity with the trading protocol.

Once we have completed the practice rounds, you will be assigned the role of buyer or seller. Once we have assigned your role, we will distribute the buyer and seller cards for round #1 and begin the portion of the experiment that will influence your earnings for today's session. We will begin the first practice round. You have 3 minutes to trade. Go!

We will now do 4 real rounds. Earnings are denominated in $. Your total earnings for the session will be the sum of your earnings from all 4 rounds. In a similar market to the one you are about to participate in, a trade occurred at price $X. You may now begin trading.

PRELIMINARY RESULTS

Preliminary Result 1a: Data from the two experimental locations (GMU, UTK) can be pooled.

We conducted eight Kolmogorov-Smirnov tests for the equality of the distribution functions across locations, covering the two surplus levels, the two induced prices, and the two trading institutions. All fail to reject the null of equality. Table A4 shows the results.

Table A4: Results of Kolmogorov-Smirnov Tests of Equality across Experimental Location

Surplus	Induced price	Institution	K-S test p-value
Low	Low	DOA	0.294
High	Low	DOA	0.737
Low	High	DOA	0.976
High	High	DOA	0.294
Low	Low	Chamberlin	1
High	Low	Chamberlin	0.759
Low	High	Chamberlin	0.353
High	High	Chamberlin	0.614

Preliminary Result 1b: Data from the two additive displacements within a surplus level can be pooled.

We conducted eight Kolmogorov-Smirnov tests for the equality of the distribution functions across each pair of markets within a surplus level, covering the two surplus levels, the two induced prices, and the two trading institutions. All fail to reject the null of equality. Table A5 shows the results.

Table A5: Results of Kolmogorov-Smirnov Tests of Equality across Additive Displacement

Surplus	Induced price	Institution	K-S test p-value
Low	Low	DOA	0.294
High	Low	DOA	0.692
Low	High	DOA	0.102
High	High	DOA	0.66
Low	Low	Chamberlin	0.135
High	Low	Chamberlin	0.896
Low	High	Chamberlin	0.432
High	High	Chamberlin	1

Preliminary Result 1c: Data from the two trading institutions (Chamberlin market, DOA) cannot be pooled.

We conducted eight Kolmogorov-Smirnov tests for the equality of the distribution functions across trading institution, covering the two surplus levels, the two induced prices, and the two trading prices. One fails to reject the null of equality. Table A6 shows the results.

Table A6: Results of Kolmogorov-Smirnov Tests of Equality across Trading Institution

Surplus	Induced price	Trade Price	K-S test p-value
Low	Low	1	0.463
High	Low	1	0.757
Low	High	1	0.92
High	High	1	0.649
Low	Low	2	0.337
High	Low	2	0.017
Low	High	2	0.688
High	High	2	0.397

MAIN RESULTS

Repeating the regressions for Result 1 (models 1 and 3 in Table 4.3.1) using between variation only does not affect Result 1. The regressions are shown in Table A7.

Table A7: Regression Models Using Between Variation Only

Model	**1**	**2**
Dependent variable	Δp_1	Δp_1
Variation type	Induced/exogenous; between only	
Trading institution	Chamberlin market	Double oral auction
Surplus per trade	Low	Low
Prevailing price	-0.78***	-0.61***
Standard error	(0.19)	(0.20)
Observations	20	14
R^2	0.48	0.44

All models include a constant and time effects (both omitted from the table). Standard errors are corrected for clustering at the session level. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).

Repeating the regressions for Result 1 (models 1-4 in Table 4.3.1) using proportionate changes in the price level $(\Delta p_1)/p_1$ as the dependent variable does not affect Result 1. The regressions are shown in Table A8.

Table A8: Regression Models Using Proportionate Price Changes as the Dependent Variable

Model	**1**	**2**	**3**	**4**
Dependent variable	$\Delta p_1/p_1$	$\Delta p_1/p_1$	$\Delta p_1/p_1$	$\Delta p_1/p_1$
Variation type	Induced/exogenous			
Trading institution	Chamberlin market		Double oral auction	
Surplus per trade	Low	High	Low	High
Prevailing price	-0.027***	-0.014***	-0.020***	-0.017***
Standard error	(0.0060)	(0.0024)	(0.0060)	(0.0036)
Observations	40	39	28	28
R^2	0.34	0.46	0.31	0.46

All models include a constant and time effects (both omitted from the table). Standard errors are corrected for clustering at the session level. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).

Repeating the regressions for Result 1 (models 1-4 in Table 4.3.1) omitting either (1) all observations where the first trade price is equal to the induced price or (2) all observations where the first trade price is within $1 of the induced price does not affect Result 1. The regressions are shown in Table A9a (first trade price equal to induced price dropped) and Table A9b (within $1 dropped).

Table A9a (Top) and A9b (Bottom): Regression Models Where "Priming" Observations Are Dropped

Model	**1**	**2**	**3**	**4**
Dependent variable	Δp_1	Δp_1	Δp_1	Δp_1
Variation type	Induced/exogenous			
Trading institution	Chamberlin market		Double oral auction	
Surplus per trade	Low	High	Low	High
Prevailing price	-1.0***	-0.64***	-0.85***	-0.77***
Standard error	(0.17)	(0.11)	(0.17)	(0.14)
Observations	33	33	22	27
R^2	0.60	0.45	0.70	0.57

Model	**1**	**2**	**3**	**4**
Dependent variable	Δp_1	Δp_1	Δp_1	Δp_1
Variation type	Induced/exogenous			
Trading institution	Chamberlin market		Double oral auction	
Surplus per trade	Low	High	Low	High
Prevailing price	-1.4***	-0.56**	-0.98***	-0.82***
Standard error	(0.31)	(0.20)	(0.24)	(0.16)
Observations	21	24	14	22
R^2	0.68	0.27	0.74	0.64

All models include a constant and time effects (both omitted from the table). Standard errors are corrected for clustering at the session level. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).