The nature of excess: Investigating price dynamics[1]

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PRELIMINARY DRAFT – PLEASE DO NOT CITE

Abstract

A Chamberlin market is a trading institution with multiple traders, decentralized bilateral bargaining and publicly declared transaction prices (Chamberlin (1948)). This paper investigates the determinants of price dynamics in Chamberlin markets as well as double oral auctions. We test and compare the excess supply model (Walras (1874, 1877, 1889, 1896) and the excess rent model (Smith (1962, 1965)) and find support for the excess rent model. Unlike existing studies, which rely on natural variation in the main treatment variable (the prevailing price), we implement randomized control in the main treatment variable. We find that Smith's (1965) support for the excess rent model did not suffer from endogeneity bias.

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1. Introduction

What determines price dynamics when markets are in disequilibrium? This conundrum, which is central to so much of economics, has commanded the interest of scholars for over a century, yet a thorough solution remains beyond our grasp. This paper takes a step towards furnishing an answer.

The Walrasian excess supply model (Walras (1874, 1877, 1889, 1896)) is the simplest and most famous model. It predicts that in the presence of excess supply, sellers will drive the price down as they scramble for scarce buyers. The larger the excess supply, the more vigorous the sellers' attempts and so the faster the decline in prices.[3] Since Smith's (1962, 1965) introduction of a double oral auction, countless studies of experimental markets have found support for Walras' model (see Cason and Friedman (1993) for a review).[4]

During his investigation of the Walrasian mechanism, Smith presented a refinement of the excess supply model, which he termed the excess rent model. Excess rent (see Figure 1) is the total rent that would be obtained if all those who want to trade at the prevailing price were to trade (i.e., ignoring imbalances in supply and demand) minus the total rent at the competitive equilibrium.

The excess rent model predicts that the greater the excess rent, the faster prices head towards equilibrium. Traders on the long side of the market drive prices towards equilibrium not only as a function of their desire to secure a trade (the Walrasian model), but also as a function of the profitability of the trade. Excess rent is a measure of how much people who are failing to trade at the prevailing price lose by this failure, and thus how aggressive they will be in their price offers.

Despite the centrality of the market mechanism to the economics discipline, there is a dearth of models that yield testable predictions about price dynamics.[5] Moreover neither the excess supply nor excess rent models have rigorous microfoundations.[6] A large literature on the microfoundations of competitive equilibria emerged to rectify this, building on the theoretical bargaining literature of the 1980s.[7] A major strand investigated whether price-taking competitive equilibria could emerge as the outcomes of

[3] See Alton and Plott (2008) for more on this.

[4] Though not relevant for testing the excess supply model, it is worth noting other trading institutions that succeed in attaining competitive equilibrium. For the tatonnement system, see Joyce (1984), Bronfman et al. (1996), Joyce (1998) and Plott and George (1992). For single call markets, see Cason and Friedman (1997). Also see Alton and Plott (2007) for a continuous-time extension of classical experimental markets.

[5] Plott and George (1992) consider an alternative to Walrasian stability called Marshallian stability, and in empirical testing they find support for the latter. However the Marshallian model only generates predictions that differ to the Walrasian model when at least one out of supply and demand has a perverse slope. For a deeper look at some testable predictions about other aspects of double oral auctions, see Cason and Friedman (1993) and Cason and Friedman (1996). For an investigation of price dynamics in a double auction with three commodities (rather than the usual case of one commodity) see Anderson et al. (2004).

[6] Interestingly, Walras never came up with the idea of a central auctioneer, nor did he even mention any institution that could even vaguely be contorted into a centralized market mechanism (Walker (1996)). Walras' description of the equilibration process clearly corresponded most closely to what we refer to as a Chamberlin market, i.e., bilateral decentralized bargaining between multiple traders with public prices (Chamberlin (1948)).

[7] See Osborne and Rubinstein (1990) for a review of the theoretical bargaining literature.

markets with bilateral negotiation as frictions tended to zero (frictions such as the discount rate or explicit bargaining costs).[8]

These models were essentially interested in properties of equilibria and not with explicit predictions or explanations of price movements en route to equilibrium.[9] Gjerstad and Dickhaut (1998) is middle-ground in the sense that it delves deeply into the micro behavior in markets but does not apply full rationality (traders are myopic and expectations are not fully rational).[10]

The functioning of markets permeates virtually every field of economics, including many policy issues. Consequently, understanding price dynamics in markets in disequilibrium is of major importance. A good departure point is a comparison of the excess supply and excess rent models.

It is tempting to use the abundant data from experimental double oral auctions to compare the two models, but there is an identification issue. When at least one out of demand and supply is strictly monotonic (almost always the case), then there is a bijective relationship between excess supply and excess rent. This presents two options to the researcher.

First, the researcher can simply accept that there is nothing in the theory alone that permits discriminating variation in excess supply/rent.[11] Consequently studies that have found support for the excess supply model have implicitly also found support for the excess rent model.

Second, the researcher can make functional form assumptions, e.g., Alton and Plott (2008) assume a linear model. The problem with this approach is the assumption is arbitrary; while econometricians regularly assume linearity, it is extremely rare that the linearity is a necessary condition for identification. Moreover using their data, they find little evidence of the econometric superiority of one model over the other, casting doubt over how useful such arbitrary assumptions are.

Smith (1965) was able to sidestep this problem. He noted that in a 'swastika' demand and supply system (Figure 2), for a range of prices, excess supply is constant but excess rent still varies. This allowed Smith to compare the predictions of the two models using data from experimental swastika double oral auctions, where he found support for the excess rent model.

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[8] See for example Rubinstein and Wollinsky (1985, 1988, 1990), Gale (1987), Kultti (2000), Blouin and Serrano (2001), Mortensen and Wright (2001), Moreno and Wooders (2002) and Serrano (2002).

[9] This was probably at least in part due to the analytical complexity of the models. Another strand of the literature looked at the properties of bilateral bargaining but without taking the limit as frictions go to zero. See for example Cramton (1984), Perry (1986), Chatterjee and Samuelson (1987), Samuelson (1992) and Taylor (1995). Rustichini et al. (1994) and Cason and Friedman (1997) examine similar issues in single call markets rather than bilateral negotiations.

[10] Cason and Friedman (1993) also present some market models with testable predictions. However they are either based on comparatively stylized forms of bounded rationality or the sharper predictions (such as the order in which traders trade) do not pertain to the path of prices.

[11] Technically, excess supply and excess rent are not variation free (see Heckman (2000)). If either model made specific functional form predictions, then one might still be able to compare them. However both only provide qualitative predictions.

As mentioned above, the excess supply and excess rent models are both derived intuitively rather than with rigorous microfoundations, and so the behavior and resulting predictions potentially apply to a range of market institutions, including the double oral auction. Chamberlin markets, which have bilateral decentralized bargaining between multiple traders with public prices (Chamberlin (1948)), can also serve as testing grounds for the two models. Using strictly monotonic demand and supply systems, several studies have found support for the indistinguishable predictions of the excess supply and excess rent models.[12]

In this paper, we extend Smith (1965) by collecting data in experimental Chamberlin markets with swastika demand and supply systems. Much like the theoretical literature of the 1980s, we regard Chamberlin markets as a realistic description of many markets therefore they are a substantial source of evidence on models of price dynamics.

In addition to extending Smith (1965) to a new trading institution, we also introduce design improvements, the most important of which is implementing randomized control on the prevailing price, which is the treatment variable. To the best of our knowledge, all previous studies have relied on naturally occurring variation in the prevailing price, and so they risk endogeneity bias.[13] We induce the prevailing price by declaring to traders – immediately prior to the start of trading – that: "in a similar market to the one you are about to participate in, a trade occurred at price X," where X is randomly selected.[14] A retrospective look at Smith's (1965) data suggests that his reliance on naturally-occurring data was erroneously driving his rejection of the Walrasian model (we elaborate in the experimental design section).

To facilitate comparison of our study to Smith (1965), we also collect data from double oral auctions. Further, since each market has multiple trades, we can use naturally occurring variation in the prevailing price for identification in addition to the exogenous induced variation.

We have two results. First, we find strong support for the excess rent model over the excess supply model in both Chamberlin markets and double oral auctions. Second, we find that this support does not depend upon whether variation in the prevailing price is natural or induced: Smith's (1965) results were not driven by endogeneity bias.

This paper is organized as follows. Section 2 the experimental design. Section 3 is the empirical results. Section 4 is the conclusion.

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[12] See Hong and Plott (1982), Joyce (1983), List (2004) and List and Price (2005).

[13] Crockett et al. (2009) independently and simultaneously noted this and offered their own method of generating exogenous variation, which we discuss below.

[14] Plott and George (1992) announce prices prior to the start of trading, but they do this for a different reason to us and in a different way. They construct demand and supply systems which have multiple equilibrium types to see which equilibria are most stable. Natural variation in prices seldom led to the subjects starting in one of the equilibrium types, precluding a test of its stability, and so the authors used announcements to induce the subjects into the desired equilibrium. Thus their motivation was nothing to do with addressing potential endogeneity. Moreover, they never used variation in an induced price as a (randomized) treatment variable.

2. Experimental design

A. Research questions and identification strategy

Let p_{t-1} denote the prevailing price at time t and let $\Delta p_t = p_t - p_{t-1}$ denote the rate of change of prices at time t.

Research question 1: In a swastika demand and supply system, what is the causal effect of the prevailing price(p_{t-1}) on the rate of chance of prices (Δp_t)?

Walras' excess supply model predicts a causal effect of zero, while Smith's excess rent model predicts a negative causal effect.[15] However this is an oversimplification; there is in fact a subtle identification problem that requires additional consideration.

As Smith (1965) himself noted, one cannot get too close to the equilibrium price p^* as the excess supply model suffers from a floor effect. It predicts a constant discrete rate of change of prices D whatever the prevailing price p_{t-1} unless $p_{t-1} + D \leq p^*$, in which case it predicts that the prices simply fall to equilibrium (otherwise there would be oscillation). This implies that if identifying variation in p_{t-1} occurs in the range $p_{t-1} \in [p^*, p^* + D]$, then the excess supply and excess rent models are once again indistinguishable.

Naturally, if D is known, then one need only avoid the region $[p^*, p^* + D]$. Unfortunately there are no grounds for reliably specifying D ex ante. Smith assumed that $D \leq \$0.05 = 0.045(v - c)$, i.e., within 4.5% of the trading tunnel's height from the equilibrium price, and he showed that his results were unaffected by dropping data points in the relevant range. However as we demonstrate in the appendix, his results are not robust to assuming a larger value of D. If, for example, one allows for the possibility that $D = 0.25(v - c)$ and drops the offending data (which still leaves plenty of data), then one can no longer reject a zero causal effect of p_{t-1} on Δp_t: the excess supply model seemingly outperforms the excess rent model.

With this in mind, we have developed an alternate strategy – we manipulate p_{t-1} to ensure that it is well away from the equilibrium. Naturally, experimenter manipulation and randomization go hand in hand. As we will demonstrate in the results section, our strategy leads to a resurrection of Smith's potentially erroneous siding with the excess rent model. In the next sub-section, we explain our manipulation and randomization method.

Research question 2: Does the answer to research question 1 depend upon whether the prevailing price (p_{t-1}) is randomly induced vs. naturally occurring?

Experimenter control over treatment variables (and the concomitant randomization) is desirable even if a plausible endogeneity story about natural data fails to spring to mind. However in this case there are explicit grounds for doubting Smith's (1965) results.

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[15] Actually, Walras' model also predicts a negative causal effect under certain circumstances. See the discussion following research question 2.

B. Procedure

1. Market structure

Following Smith (1965), to discriminate between the excess supply and excess rent models, we use a swastika demand and supply system with two buyers with value v and four sellers with cost c, implying a constant excess supply of 2 units. No information about any aspect of the market is given to the subjects beyond generic instructions on how to trade. To ensure that the results are not driven by unfamiliarity with the protocol, subjects participate in four swastika markets.[16] This carries the risk of subjects augmenting their learning about the protocol with learning about the values/costs of the market. To combat this, we employ several strategies.

First, values and costs are displaced by a common additive constant between rounds. Thus for example if in round 1, $v = \$20$ and $c = \$10$, then in round 2 they might be $v = \$75$ and $c = \$65$. This process and the values of the constants are not declared to the subjects. Moreover the chosen constants ensure no overlap of the bargaining tunnels between any two rounds.

Second, we vary the surplus in each swastika system. For two of the rounds, the available surplus per trade is \$8 (low surplus), while for the other two it is \$16 (high surplus). Subjects alternate which they play (again unbeknownst to them). Having two substantively different systems also serves as a simple robustness check.

Third, in addition to the six 'active' traders, there are four 'inactive' traders in each round. Two are buyers with values that are below c and two are sellers with costs that are above v (see Figure 3). Unbeknownst to them, the inactive traders can never trade in the round (only trades that imply weakly positive earnings for both traders are permitted).

Finally, which trader is active or inactive in a particular round changes over the four rounds. It is common knowledge that buyers (sellers) remain buyers (sellers) for all four rounds, but each buyer is active for two, while each seller is active for between two and four.

To summarize, each session has 10 subjects who are randomized an ID (from ID1 to ID10) at the beginning of the session. They then participate in four real rounds of trading with the values/costs in Table 1. Each round has exactly two trades.

To maximize clarity, values/costs are denominated in US\$ and gross earnings for each subject are simply the aggregate of that subject's earnings across all four rounds. Each trader also receives a trading commission of \$0.25 per trade.

[16] Prior to the four real rounds, subjects also do two practice rounds – one as a seller and one as a buyer – to further promote familiarity with the trading procedure.

2. Trading rules

The 10 subjects are seated facing the monitor. We run principally Chamberlin markets, but to facilitate comparability with Smith (1965) we also run some double oral auctions.[17]

Chamberlin markets operate according to the following rules. Each trading round lasts 3 minutes. During a trading round, negotiations can take almost any form.[18] Subjects are instructed to approach the monitor after agreeing upon a contract. The monitor ensures that the trade is legitimate (both subjects are earning weakly positive amounts), after which the monitor publicly declares the trade price.[19]

3. Price inducement and treatments

In each round, after value/cost cards are handed to each subject, the monitor makes the following statement:

> "In a similar market to the one you are about to participate in, a trade occurred at price \$$X$. You may now begin trading."

The prevailing price X is randomized. This is an important design innovation. Previous studies of price dynamics (both Chamberlin markets and double oral auctions) have relied exclusively on natural variation in the prevailing price and therefore risk endogeneity bias. Moreover as we discussed in section 2.A, a reexamination of Smith's (1965) data suggests that his conclusions are sensitive due to an absence of experimenter control over the prevailing price.

There are alternative inducement mechanisms. One is to wait for a certain amount of time after the start of trading and then make a comparable statement. In principle this decreases the risk of a priming effect of our statement. Another alternative is to introduce confederates and to have them trade at a pre-arranged, randomized price after a certain amount of time.

We reject both these alternatives for the same reasons. First, piloting indicated that the first trade would often happen very quickly (within 20 second or less of the beginning of trading). Second, negotiations were often so vigorous that subjects would not be paying much attention to such a statement by the monitor. (In double oral auctions, at most one person is talking at any point and so prices of completed trades are very salient.) In the furious trading-pit environment of a Chamberlin market with excess supply, our chosen method of inducing prices was likely the highest-power method of testing the excess rent model.

Independently of this study (and simultaneously), Crockett et al. (2009) implemented a different method for generating exogenous variation in the prevailing price: explicit price controls, i.e., preventing

[17] See Smith (1965) for the double oral auction procedure used.

[18] No inappropriate threats, no side payments and no revelation or discussion of values/costs.

[19] The substantive differences in the double oral auctions is that the only communication permitted is bids and offers when called upon by a monitor (the subject must raise his/her hand).

participants from trading below or above certain prices.[20] For their study (testing the Gale model), this method served its purpose well, as all they needed was for an exogenous way of having trades occur within a certain range.

However for the purposes of comparing the excess supply and excess rent models, we feel that our method adds an important dimension. Making a price announcement about a trade occurring in a similar market is a good simulation of the information content usually carried by naturally occurring prevailing prices. Traders can look at their values/costs and make an inference about their standing compared to the market, since the prevailing price gives them an lower (upper) bound on the value (cost) of at least one trader. 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.

Under the assumption that shifting the values/costs by a common additive constant does not affect market dynamics (an assumption that we test below and fail to reject), our sessions look at two markets only: $8-per-trade surplus and $16-per-trade surplus. Another design innovation is that our inference will be based on different prevailing prices (p_{t-1}) in the same demand and supply system. In existing studies, e.g., Smith (1965), observations are collected from multiple trades in multiple demand and supply systems. The author then pools the data and estimates:

$$\Delta p_t = \alpha + \beta(p_{t-1} - p^*) + \varepsilon$$

A demand and supply system is defined by the values/costs of its participants. Every time a pair of traders strike a deal and exit the market, the system has changed as there are now two fewer traders. The change is unlikely to be appreciable in real markets with hundreds or thousands of traders, but in a market with below 30 traders, the two traders exiting represent anywhere from 7%-33% of the market.[21] Moreover in non-swastika 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.

This is important because the above econometric specification with pooled data imposes a causal effect of excess supply or excess rent that is independent of the characteristics of the demand and supply system. Using Smith's (1965) data to attempt to partially correct for this again casts doubt on the robustness of his results (see the appendix for details). Conducting the inference only on the systems with the same constant excess supply leads to mixed or absent support for the excess rent model.

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[20] Plott (2000) had previously used price controls, but never to address potential endogeneity bias; rather he was doing it to expand the support of the treatment variable, e.g., to see what happens when prices are near a certain equilibrium. In other words, his is a variant on the method used in Plott and George (1992).

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

There is nothing in the formulation of either the excess supply or excess rent model that requires structural causal effects to be identical across demand and supply systems. The models make predictions only about causal effects within a system defined in the narrowest possible sense.

All of our identification is based on prevailing prices that vary across identical demand and supply systems. Thus we will be comparing behavior from the same round between sessions. This raises the question of which induced prices maximize power.

The excess rent model predicts a monotonic relationship between excess rent and price movements. Moreover while there may be heteroskedasticity in price movements, we had no a priori reason to expect any particular form of heteroskedasticity. Thus the highest power test would be to share the observations equally between the highest and lowest possible trade prices only.

However as Smith (1965) noted and as discussed above, one cannot get too close to the equilibrium price p^* as the excess supply model suffers from a floor effect. Smith assumed that this floor occurred at 4.5% of the constant per-trade surplus above p^*.

We provide extra clearance by selecting a low induced price that is 25% of the constant per-trade surplus above p^*. On the high side we selected an induced price that is 75% of the constant per-trade surplus above p^*. We wanted to avoid the highest possible price because we wanted to be able to check for a priming effect, and this would require trade prices to be both above and below the induced price.

Table 2 details the high and low induced prices used in each round. We ran two session types: in session type 1, the induced price sequence across the four rounds was *low-low-high-high*, while in session type 2 it was *high-high-low-low*.

3. Empirical results

We ran 20 Chamberlin market sessions and 14 double oral auction sessions in two locations (George Mason University and University of Tennessee at Knoxville).[22] Subjects were recruited using campus databases of subjects who had declared an interest in being subjects in economics experiments. Including check-in and payment processing, sessions lasted approximately 45 minutes and subjects earned an average of $20.

Summary statistics on all the data are in the appendix. Kolmogorov-Smirnov and Mann-Whitney tests suggest that we can pool Chamberlin market and double oral auction data. However for completeness we separate the results.

Each session had four markets where the active buyers had a common value v and the active sellers an active cost c. Each market had an induced price p_0, which takes one of two values: a low one,

[22] Kolmogorov-Smirnov tests confirm that we can pool data across the two locations.

$p_0^L = c + 0.25(v - c)$ and a high one, $p_0^H = c + 0.75(v - c)$. Two trades occur at prices p_1 and p_2. Let $\Delta p_1 = p_1 - p_0$ and $\Delta p_2 = p_2 - p_1$.

- For identification using exogenously induced variation, the treatment variable is p_0 and the outcome variable is Δp_1.
- For identification using naturally occurring variation, the treatment variable is p_1 and the outcome variable is Δp_2.

As described in section 2.B.3, we ran two versions of each system, where each version is identical save for the values and costs being displaced by a common additive constant. To increase power, we would like to pool data within any such pair. Given the system's surplus (low vs. high), induced price (low vs. high) and trading institution (Chamberlin vs. DOA), we had 8 pairs. We ran Kolmogorov-Smirnov tests on each pair where the outcome variable is the difference between the induced price and the price of the first trade. We failed to reject equality in all pairs.[23]

Result 1: In a swastika demand and supply system, the causal effect of the prevailing price (p_0) on the rate of chance of prices (Δp_1) is negative in both Chamberlin markets and double oral auctions. This supports Smith's excess rent model over Walras' excess supply model.

Given the pooling, there are four types of market: high ($16) vs. low ($8) surplus and Chamberlin vs. double oral auction. Using exogenously induced variation, there are two treatments for each market: a low induced price and a high induced price. If we normalize the estimated treatment effects so that they correspond to a $1 increase in the induced price, the estimated treatment effects are:

- -0.87 (40 observations; p-value < 1%) in a low surplus Chamberlin market.
- -0.64 (39 observations; p-value < 1%) in a high surplus Chamberlin market.[24]
- -0.64 (28 observations; p-value < 1%) in a low surplus double oral auction.
- -0.77 (28 observations; p-value < 1%) in a high surplus double oral auction.

P-values correspond to Mann-Whitney tests. The estimated treatment effects are all economically and statistically significant. We can introduce additional controls at the expense of a parametric specification by estimating the following model for each of the four markets:

$$\Delta p_1 = \alpha + \beta p_0 + \sum_{j=1}^{4} \delta_j T_j + \varepsilon$$

T_j is a dummy variable taking the value 1 in round j. We allow for session-clustering in the error term.[25] The results are in Table 3. They mirror the unconditional results.

[23] A similar failure to reject equality is obtained if we use Mann-Whitney tests with two exceptions: low surplus / high induced price / Chamberlin market is significant at the 7% level and and low surplus / low induced price / double oral auction is significant at the 5% level. However as we demonstrate below, including session and round controls in a regression framework affects none of our results.

[24] We lost one observation from the high surplus Chamberlin markets.

We have used the absolute rate of change of prices as the outcome variable. Technically, neither the excess supply nor the excess rent models specify using the absolute rate of change of prices, and so one could plausibly use the proportionate rate of change $(\Delta p_1)/p_1$ instead. Doing so does not affect result 1 (results omitted for parsimony and available upon request).

We have used a mixture of between and within variation to estimate causal effects (clustered standard errors are not elixirs). An even more conservative approach is to use the data from the first round of each session only, i.e., exclusively between variation. Since we did not use a full-factorial design, we can only do this for the low surplus Chamberlin and double oral auction markets. Result 1 is again unaffected.

As a final robustness check, recall that we induce the prevailing price by making a statement about an actual trade price in a similar market in a previous session. Since this information is delivered by the monitor, there is a risk of an experimenter demand effect. The subjects could consciously or unconsciously be primed to seek a trade at the announced prevailing price.

To see if result 1 is sensitive to this possibility, we repeat the hypothesis tests 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. Result 1 is not affected.

Result 2: Result 1 is unaffected by using naturally occurring data. This suggests that Smith's (1965) support for the excess rent model was not driven by endogeneity bias.

In the naturally occurring data, the treatment variable is the first trade price, p_1. Unlike the induced price p_0, this takes many values and so we are forced to use a parametric model to estimate the causal effect. The results are in Table 4.

In all four markets, the causal effect of the prevailing price on the rate of change of prices is negative. It is tempting to compare the magnitudes of the coefficients from the naturally occurring data to those from the exogenous data. However these are different markets: there are two less traders, so the demand and supply system has changed.

Like result 1, result 2 is also robust to using proportional rates-of-change in prices, as well as using exclusively between-session variation (round 1 data only).

4. Conclusion

The excess supply and excess rent models can potentially yield a rich array of testable predictions. However their intuitive derivation means that they only generate one qualitative prediction, and it is

[25] Regressing the discrete rate of change of prices on the prevailing price can generate a negative correlation in the absence of an economically founded, structural link between the two. We expand upon this in the appendix and demonstrate that our results are not spurious.

one that they share for most demand and supply systems. This is almost certainly a consequence of the intractability of formal presentations of the two models.

The swastika demand and supply system allows us to discriminate between the models. Using randomized control in the main explanatory variable (the prevailing price) we find strong support for the excess rent model in both Chamberlin markets and double oral auctions. We also find that Smith's (1965) earlier finding of support for the excess rent model in double oral auctions, which was based on naturally occurring variation in the prevailing price, was not driven by endogeneity bias.

Understanding price dynamics is of major importance since markets are the cornerstone of so much of the policy analysis conducted by economists. It is our hope that this study can help reinvigorate research in this critical field. Fleshing out the microfoundations of the excess rent model to generate additional testable predictions is a promising avenue for future research.

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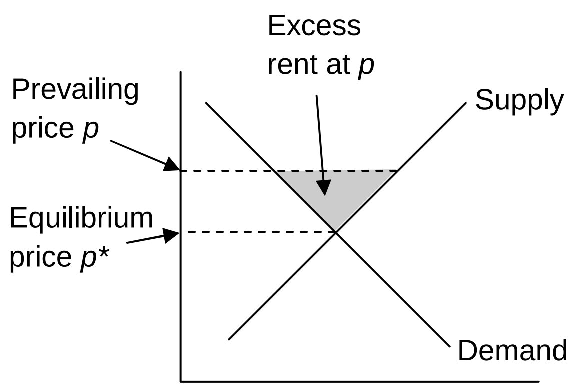

Figure 1: Excess rent

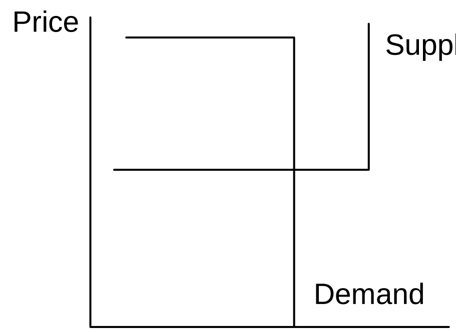

Figure 2: Smith's swastika (constant excess supply) system

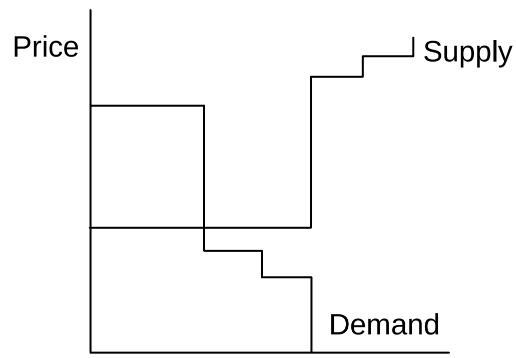

Figure 3: Swastika demand and supply system used in experiments

ID	Role	Round 1 value/cost	Round 2 value/cost	Round 3 value/cost	Round 4 value/cost
1	Buyer	$21	$24	$80	$66
2	Buyer	$21	$41	$81	$49
3	Buyer	$12	$41	$90	$48
4	Buyer	$11	$23	$90	$66
5	Seller	$13	$42	$91	$50
6	Seller	$13	$25	$92	$67
7	Seller	$13	$25	$82	$68
8	Seller	$13	$25	$82	$50
9	Seller	$22	$25	$82	$50
10	Seller	$23	$43	$82	$50

Table 1: Roles, values and costs for the 10 subjects by round

Shaded values correspond to 'active' traders, i.e., those who have a value/cost that actually permits trade. Rounds 1 and 3 are low surplus ($8 per trade) and 2 and 4 are high surplus ($16 per trade).

Session type	Round 1	Round 2	Round 3	Round 4
1	$15 ($13, $21)	$29 ($25, $41)	$88 ($82, $90)	$62 ($50, $66)
2	$19 ($13, $21)	$37 ($25, $41)	$84 ($82, $90)	$54 ($50, $66)

Table 2: Induced prices by round and session type

The first number in each cell is the induced price. The first number in parentheses is the cost of the active sellers, and the second number is the value of the active buyers.

Trading institution Surplus per trade	Chamberlin market Low	Chamberlin market High	Double oral auction Low	Double oral auction High
Prevailing price (p_0)	-0.88***	-0.64***	-0.64***	-0.77***
Standard error	(0.15)	(0.09)	(0.15)	(0.13)
Observations	40	39	28	28
R^2	0.54	0.52	0.50	0.58

Table 3: Regression model of the causal effect of the prevailing price on the rate of change of prices using exogenously induced variation in the prevailing price

The dependent variable in all regressions is Δp_1. All models include a constant and time effects (both omitted from the table). Standard errors are corrected for clustering. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).

Trading institution Surplus per trade	Chamberlin market Low	Chamberlin market High	Double oral auction Low	Double oral auction High
Prevailing price (p_1)	-0.82***	-0.93***	-0.30*	-0.23**
Standard error	(0.18)	(0.21)	(0.15)	(0.08)
Observations	40	39	28	28
R^2	0.55	0.51	0.15	0.16

Table 4: Regression model of the causal effect of the prevailing price on the rate of change of prices using natural variation in the prevailing price

The dependent variable in all regressions is Δp_2. All models include a constant and time effects (both omitted from the table). Standard errors are corrected for clustering. Asterices denote statistical significance (* = 10%, ** = 5%, *** = 1%).

Appendix A: Analyzing Smith's (1965) data

We reconstructed Smith's data by studying the figures in his paper. In principle, they show all the data, though the grid has some imperfections and so the dataset that we have constructed is not exactly the same as the original. Nevertheless, using Smith's regression tables as a benchmark, we are able to achieve a high degree of accuracy in our recovered data. Table A1 is recreation of Table 2 from Smith (1965), and Table A2 is our attempt at reproducing it.

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

Table A1: Table 2 from Smith (1965)

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

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

Table A2: Attempted reconstruction of Table A1 using data inferred from charts

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

Visual inspection confirms that our reconstruction is extremely accurate.

In Table A3, we extend the models that Smith estimated.[26] In models 1 and 2, we increase the proportion of prices that he dropped from 4.5% to 25%. In one of the two, excess rent loses its statistical significance.

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

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

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

Smith (1965) pooled data from three different swastika systems: one with a constant excess supply of 2 units, one with 5 units and one with 8 units. It is reasonable to expect that the causal effect is heterogenous across these systems. Models 3-to-5 replicate model 5 from Table A1 and Table A2, but each time we condition on one of the three possible constant excess supplies. Models 6-to-8 replicate 3-to-5 but with 25% of the tunnel dropped. Only one of the six regressions yields a significant effect excess rent.

The conclusion to draw from this is that the results demonstrate substantial sensitivity to reasonable variation in the specification and included data. Working with more narrowly defined cells and with randomly induced variation in the prevailing price is important for a critical reassessment of the excess rent model.

[26] 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.

Appendix B: Summary statistics

System	Induced price	Trade price 1	Trade price 1 minus Induced price	Trade price 2	Trade price 2 minus Trade price 1
Low surplus ($8) system 1: c = $13, v = $21	Low: 15	15.7	0.7	15.5	-0.2
		(1.6)	(1.6)	(0.8)	(1.9)
	High: 19	16.6	-2.4	16.3	-0.3
		(1.7)	(1.7)	(1.3)	(2.0)
Low surplus ($8) system 2: c = $82, v = $90	Low: 84	84.1	0.1	82.6	-1.5
		(1.9)	(1.9)	(0.9)	(2.5)
	High: 88	84.2	-3.8	83.8	-0.4
		(1.8)	(1.8)	(1.9)	(1.4)
High surplus ($16) system 1: c = $25, v = $41	Low: 29	28.6	-0.4	28.1	-0.5
		(2.6)	(2.6)	(1.6)	(3.3)
	High: 37	30.9	-7.1	30.0	-0.9
		(2.7)	(2.7)	(3.7)	(4.9)
High surplus ($16) system 2: c = $50, v = $66	Low: 54	53.7	-0.3	54.0	0.3
		(0.9)	(0.9)	(1.0)	(1.4)
	High: 62	57.1	-4.9	56.2	-0.9
		(3.3)	(3.3)	(3.0)	(4.9)

Table A4a: Descriptive statistics for the Chamberlin markets

System	Induced price	Trade price 1	Trade price 1 minus Induced price	Trade price 2	Trade price 2 minus Trade price 1
Low surplus ($8) system 1: c = $13, v = $21	Low: 15	15.3	0.3	15.3	0.0
		(1.3)	(1.3)	(1.1)	(1.0)
	High: 19	16.9	-2.1	16.7	-0.1
		(1.7)	(1.7)	(1.8)	(1.6)
Low surplus ($8) system 2: c = $82, v = $90	Low: 84	83.1	-0.9	83.4	0.3
		(0.9)	(0.9)	(0.5)	(0.8)
	High: 88	84.4	-3.6	83.5	-0.9
		(2.1)	(2.1)	(2.5)	(1.6)
High surplus ($16) system 1: c = $25, v = $41	Low: 29	29.1	0.1	27.6	-1.6
		(2.8)	(2.8)	(2.1)	(1.3)
	High: 37	30.7	-6.3	30.3	-0.4
		(3.8)	(3.8)	(3.7)	(1.8)
High surplus ($16) system 2: c = $50, v = $66	Low: 54	53.3	-0.7	51.4	-1.9
		(2.0)	(2.0)	(1.5)	(1.7)
	High: 62	55.4	-6.6	54.6	-0.8
		(2.4)	(2.4)	(1.4)	(2.0)

Table A4b: Descriptive statistics for double oral auctions

Figures without parentheses are sample means. Figures with parentheses are the sample standard deviations for the variable in the cell above. Data with a gray background is a discrete rate-of-change.

Appendix C: Regressing Δp_t on p_{t-1}

Suppose that the data generating process is:

$$p_t = \alpha + \beta p_{t-1} + u, \qquad -1 < \beta < 1$$

Where u is exogenous white noise. This is a stationary process with $E(p_t) = \alpha/(1-\beta)$. Let p^* be the economically predicted equilibrium price (i.e., the intersection of demand and supply). The excess rent model predicts either $0 < \beta < 1$ or $(\beta = 0, \alpha = p^*)$. The pure white noise process $(\beta = 0, \alpha \neq p^*)$ is inconsistent with the excess rent model. If we estimate the model:

$$\Delta p_t = \alpha + \theta p_{t-1} + u$$

Then $\hat{\beta} = \hat{\theta} + 1$. Thus while $-1 \leq \hat{\theta} < 0$ is necessary for the excess rent model, it is not sufficient. If we find that $\left(\hat{\theta} = -1, \alpha \neq p^*\right)$ then the data generating process is possibly just pure white noise.

We have four markets: high vs. low surplus and Chamberlin vs. double oral auction. In all four, we strongly reject the hypothesis that $\alpha = p^*$. In three out the four (all but high surplus Chamberlin), we reject $\hat{\theta} = -1$ (two at the 5% level, one at the 10% level).

Appendix D: 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 is 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.