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COMPETITION IN LARGE MARKETS

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ABSTRACT

This paper develops a simple and robust implication of free entry followed by competition without substantial strategic interactions: Increasing the number of consumers leaves the distributions of producers' prices and other choices unchanged. In many models featuring non-trivial strategic considerations, producers' prices fall as their numbers increase. Hence, examining the relationship between market size and producers' actions provides a nonparametric tool for empirically discriminating between these distinct approaches to competition. To illustrate its application, I examine observations of restaurants' seating capacities, exit decisions, and prices from 224 U.S. cities. Given factor prices and demographic variables, increasing a city's size increases restaurants' capacities, decreases their exit rate, and decreases their prices. These results suggest that strategic considerations lie at the heart of restaurant pricing and turnover.

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1 Introduction

Consider competition in a large market. Producers' strategies potentially depend on a detailed description of all rivals' past actions and current opportunities, but a simple summary statistic that no individual producer can greatly influence – such as the market price or the number of customers per store – might be sufficient for describing the competitive environment. In this latter case, strategic interactions between producers are irrelevant. This paper shows that these two alternatives can be empirically distinguished without prior knowledge of the market demand system, producers' cost functions, or the variables over which they compete. Because this procedure relies on no parametric assumptions, it can be applied to observations of producer conduct in large markets before undertaking a more involved structural analysis that relies on either approach to competition.

Without strategic interaction, doubling the number of consumers leaves the distributions of producers' actions unchanged. This is familiar from the simplest model of long-run perfect competition, in which free-entry requires all producers to minimize average cost regardless of the scale or shape of the market demand curve. In Dixit and Stiglitz's (1977) model of Chamberlinian monopolistic competition, the free entry condition implies that each firm's sales equal the product of the exogenous fixed cost with consumers' constant elasticity of demand. Doubling the number of consumers leaves producers' average sales unchanged. This paper shows that the invariance of producer decisions to market size is much more general than these examples suggest. This prediction provides the basis for empirically detecting strategic interactions without detailed observations of individual producers' actions.

The analysis rests on a nonparametric free-entry model. Potential producers make entry choices and then compete across a potentially large number of variables; such as price and advertising. A producer's profit depends only on the distribution of its rivals' actions and not on any particular rival's choices. This allows the transformation of a free-entry equilibrium for a given market size into one for a larger market with the same distribution of producers' actions. Thus, the model predicts that raising market size has no impact on the distribution (across producers) of any observable producer choice.

Because the model embodies no parametric assumptions, its predictions can be used to test reliably the assumption of atomistic competition using observations of producers' actions from a cross section of markets. To illustrate its application, the paper concludes with nonparametric regressions of restaurants' prices, seating capacities, and exit rates on market size. Of course, the distribution of producers' actions could differ across large and small markets even without substantial strategic interaction if the production technology and consumer tastes systematically change with market size. The free-entry model eliminates these possibilities by assumption, and the regression controls for them with factor prices and demographic measures.

On average across the sample of 224 U.S. Metropolitan Statistical Areas, the restaurants in larger cities have lower prices, have greater seating capacities, and exit less frequently. These findings are consistent with Campbell and Hopenhayn's (2005) result that restaurants and many other retail establishments in larger cities have greater average sales and employment. Together, they favor a model of competition between restaurants in which adding a competitor lowers producers' markups. They also suggest that the strategic models of entry and pricing in small markets estimated by Bresnahan and Reiss (1990), Berry (1992), and others might enhance our understanding of competition in large markets.

The remainder of this paper proceeds as follows. The next section presents and analyzes the nonparametric model of competition without substantial strategic interaction. Section 3 empirically applies the analysis, and Section 4 relates this paper's results with those from the relevant literature. Section 5 offers some concluding remarks.

2 A General Model of Atomistic Competition

When no individual producer can greatly influence any other's profit, I label the competition between them *atomistic*. Otherwise, strategic considerations substantially shape an individual producer's profit maximization problem. I denote this case with *non-atomistic* competition. This section develops theoretical predictions of atomistic competition that can be used to test it using data from competition in large markets.

Such a prediction must not depend on unobservable institutional and strategic details. For this reason, I develop the cross-market predictions of atomistic competition in a very general model with no parametric restrictions. So that the analysis is as broadly applicable as possible, I do not present specific conditions to guarantee the existence and uniqueness of a free-entry equilibrium. Instead, the analysis begins with the assumption that an equilibrium exists for a particular market size, and it then constructs an equilibrium with the same observable distribution of producers' actions for a larger market.

Having a specific example in mind makes following the general model easier, so this section begins with a particular model of atomistic competition. It then proceeds to the general model, referring back to the specific example to explain its moving parts.

2.1 A Specific Example

Consider a market for restaurant meals of heterogeneous quality. Production takes place in two stages, entry and competition. In the entry stage, a large number of potential restaurateurs simultaneously decide whether to pay a sunk cost of i to enter the market or to remain inactive at zero cost. After the restaurateurs commit to their entry decisions, each restaurant receives a random endowment of quality, which can equal either the high value q_H with probability w or the low value q_L with the complementary probability.

The competitive stage consists of two periods, early and late. All entrants can operate with zero fixed costs in the early period, but continuing to the late period requires paying a continuation cost i'. Exit allows a restaurateur to avoid this cost. In both periods, consumers randomly match with restaurants. The market is populated by S identical consumers, and equal numbers of them match with each restaurant. Restaurateurs simultaneously post their prices, and consumers decide on their purchases. A consumer matched with a restaurant charging a price p for a meal of quality q purchases $d(p/q)$ meals. This demand function is strictly decreasing and concave. Restaurants' variable cost functions are identical and feature a constant marginal cost of production, m.

A free entry equilibrium consists of a number of entrants, N, quality-contingent pricing decisions for each of the two periods, and quality contingent exit decisions such that each active restaurateur maximizes profit, entry earns a non-negative return, and no inactive potential entrant regrets staying out of the market. It is straightforward to show that this model has a unique free-entry equilibrium. First, consider the restaurants' pricing decisions, which satisfy the usual inverse-elasticity rule.

$$\frac{p-m}{p} = \frac{p}{q}\frac{d'(p/q)}{d(p/q)}$$

Because $d(\cdot)$ is concave, there is a unique price that satisfies this for each quality level. It is also straightforward to show that the optimal price increases with the restaurant's quality.

The assumption of a constant marginal cost implies that a restaurant earns a constant profit per customer. Denote these with π_L and π_H for the low and high quality restaurants. Restaurateurs' exit decisions depend on these profits, the number of entrants, and the cost of continuation. Denote the number of active restaurants in the late period with N'. Restaurateurs' optimal continuation decisions imply that

$$N' = \begin{cases} N & \text{if } i' \leq (S/N) \times \pi_L, \\ S\frac{\pi_L}{i'} & \text{if } (S/N) \times \pi_L < i' \leq (S/wN) \times \pi_L, \\ wN & \text{if } (S/wN) \times \pi_L < i' \leq (S/wN)\pi_H, \\ S\frac{\pi_H}{i'} & \text{if } (S/wN)\pi_H < i'. \end{cases}$$

In the first case all restaurants can profitably produce during the late period. In the second case, low-quality restaurants exit until their continuation value equals zero. In the third case, all low-quality restaurants exit, but all high-quality restaurants continue. In the final case, the continuation cost is high enough so that high-quality restaurants exit until their continuation value equals zero. The equilibrium exit decisions allow the definition of low and high quality restaurants' values at the beginning of the competitive stage, $V_L(S/N)$ and $V_H(S/N)$. These are both strictly increasing in S/N, so there exists a unique value of N that equates the ex-ante value of a new entrant with the entry cost.

Before proceeding to the general model, it is worth highlighting the scale invariance of this example's free-entry equilibrium. Because the ex-ante value of an entrant depends only on S/N, increasing the number of consumers increases the number of entrants proportionately. Restaurants' optimal prices depend on neither S nor N, while increasing both S and N increases N' by the same proportion and leaves the exit rate, $1 - N'/N$, unchanged. Hence, increasing the number of consumers in the market leaves the distributions of all observable producer decisions unchanged.

Suppose that observations of average producer actions from a sample of markets are available. If restaurateurs' marginal costs and consumers' demand curves depend on a vector of market-specific variables like factor prices and demographics, then regressions of restaurants' exit rate and of the fraction of restaurants with "high" prices on this vector and S would detect no dependence of these market-level summaries of producer actions on market size. In this sense, the specific example yields a testable prediction for cross-market comparisons of producer actions. This example omits many realistic features of retail industries, so one might suspect that this scale invariance arises from its simplifying assumptions. The analysis of the general model demonstrates that models of atomistic competition robustly predict scale invariance.

2.2 The General Model

Like the specific example, the general model consists of two stages, entry and comptition. In the first stage, a large number of potential entrants simultaneously make their entry decisions. At the same time, entering producers make their product choices. The product choice of a particular entrant is x, and this lies in the set of all possible choices, $\mathcal{X} \subset \mathbb{R}^k$, where $k < \infty$. The number of producers that made choice x is $F(x) \in \mathbb{N}$, which I call the industry's *entry profile.* The example did not make restaurateurs' product choices explicit, but we can easily assume that they choose product addresses in $\mathbb{R}$ and that all consumers match in equal numbers with all offered products.

In the second stage, producers compete to sell their products to the market's S consumers. Producers simultaneously choose actions, $a \in \mathcal{A} \subset \mathbb{R}^l$, where $l < \infty$. Producers' profits depend on these choices and on realization of a vector of aggregate shocks, Z, which occurs before producers choose actions. An *action profile* is a function $A(x; Z, F) \to \mathcal{A}$. If $F(x') > 0$, then $A(x'; Z, F)$ gives the action of a producer that chose x' at entry. In the example, a represents a restaurants' early and late prices and its continuation probability and Z determines restaurants' qualities.[1]

For simplicity, we assume that if two or more entrants chose x, they both choose the same post entry action.[2] The total revenues of a producer at x' that chooses the action a' when all other producers' use the action profile $A(x; Z, F)$ and the entry profile is $F(x)$ are $S \times r(a', x'; A, Z, F)$. Here, S denotes the number of consumers and $r(\cdot)$ is the producer's average revenue per consumer, which does not directly depend on S. That producer's costs are $c(a', x'; A, Z, F, S)$. Because $c(\cdot)$ includes fixed costs and marginal cost might not be constant, it need not depend on S linearly.

The expected post entry profit to a producer choosing x' at entry when it and its com-

[1]The specific example relies on idiosyncratic shocks to entrants' qualities. To use the general model's aggregate shocks to represent idiosyncratic shocks, assume that Z is a uniformly distributed location on the unit-circumference circle and that a restaurant has high quality if the clockwise distance between x/N (interpreted as a location on this circle) and Z is less than w. A potential entrant is indifferent across all locations on $[0, N)$ if entrants uniformly distribute themselves on this interval, so such a uniform distribution is an equilibrium outcome that generates the same distribution of high and low quality as in the example.

[2]As in the specific example, an element of a can represent a mixed strategy over a discrete and finite set of actions; and the revenues and costs specified below can be reinterpreted as expected values. Hence this assumption allows for mixed strategies. However, it does remove asymmetric Nash equilibria from consideration.

petitors follow the action profile $A(x;Z,F)$ are

$$\pi(x';A,F,S) \equiv \mathbf{E}\left[S \times r\left(A\left(x';Z,F\right),x';A,Z,F\right) - c\left(A\left(x';Z,F\right),x';A,Z,F,S\right)\right].$$

Here, the expectation is taken with respect to the distribution of Z. This expectation exists under the assumption that that $r(\cdot)$ and $c(\cdot)$ are uniformly bounded functions of a and Z.

For the example, denote the prices charged by a restaurant and the probability that it produces in the late period with a_1, a_2, and a_3 The revenue and cost functions in the case where a single restaurant occupies an address are

$$\begin{aligned} r(\cdot) &= \frac{a_1}{N} \times d(a_1/q) + a_3 \times \frac{a_2}{N'} \times d(a_2/q), \text{ and} \\ c(\cdot) &= i + m \times \frac{S}{N} d(a_1/q) + a_3 \times \left(i' + m \times \frac{S}{N'} d(a_2/q)\right). \end{aligned}$$

In these expressions, the restaurant's quality q is the function of Z and x described in Footnote 1.

Define a *strategy profile* to be an action profile $A(x;Z,F)$ paired with an entry profile $F(x)$ and denote it with (A,F). With this notation in place, the definition of a free-entry equilibrium may proceed.[3]

Definition *A strategy profile* $(A^\star, F^\star)$ *is a* free-entry equilibrium *for a market with* S *consumers if it satisfies the following conditions.*

(a) Take any entry profile $F(x)$*. If* $F(x') > 0$*, then for all* $a \in \mathcal{A}$ *and all possible realizations of* Z*,*

$$\begin{aligned} &S \times r\left(a,x';A,Z,F\right) - c\left(a,x';A,Z,F,S\right) \leq \\ &\qquad S \times r\left(A^\star\left(x';Z,F\right),x';A,Z,F\right) - c\left(A^\star\left(x';Z,F\right),x';A,Z,F,S\right). \end{aligned}$$

[3]Conventional notation for a dynamic game takes a set of players with names, a strategy space, and payoff functions as primitives. The application of that approach to this model would specify the set of players as an unbounded set of potential entrants with names in R^k, the strategy space as $\mathcal{X} \times \{A(x;Z,F) \in \mathcal{A}\}$, and the payoffs as profit defined above. Because $F(x)$ and Z directly index all relevant subgames, working directly with the strategy profile as defined here simplifies the model's exposition.

(b) For all $x' \in \mathcal{X}$, $\pi\left(x'; A, F^{\star} + I\left\{x = x'\right\}, S\right) \leq 0$.

(c) If $F^{\star}\left(x'\right) > 0$; then $\pi\left(x'; A^{\star}, F^{\star}, S\right) \geq 0$, and for all $x'' \in \mathcal{X}$

$$\pi\left(x'; A^{\star}, F^{\star}, S\right) \geq \pi\left(x''; A^{\star}, F^{\star} + I\left\{x = x''\right\} - I\left\{x = x'\right\}, S\right)$$

Condition *(a)* of this definition ensures that the action profile $A^{\star}\left(x; Z, F\right)$ forms a Nash equilibrium for all subgames following the entry stage. Condition *(b)* requires that no further entry is profitable, and condition *(c)* states that each active producer's entry decision and choice of x is optimal given all other potential entrants' decisions. Together, the definition's three conditions are equivalent to requiring the strategy profile $\left(A^{\star}, F^{\star}\right)$ to correspond to a subgame perfect Nash equilibrium with pure strategies in the entry stage.

2.3 Atomistic Competition

At this level of generality, the framework encompasses many models. To specialize it and thereby derive the implications of atomistic competition, we impose the following two conditions. The first condition allows for only trivial strategic interactions between producers when no two of them occupy the same location in $\mathcal{X}$, and the second ensures that no such "local oligopolies" will arise in a free-entry equilibrium. Henceforth, I assume that $\mathcal{X}$ is a Borel measurable set with positive measure, denote the set of its Borel measurable subsets with $\mathcal{M}$, and use $\mu\left(M\right)$ to denote the Borel measure of $M \in \mathcal{M}$.

Assumption A1 (Atomistic Competition) *Let $\left(A, F\right)$ be a strategy profile with $F\left(x\right) \leq 1$ and define $M = \{x | F(x) = 1\}$. If $F(x)$ is Borel-measurable, $\mu(M) > 0$, $A(x; Z, F')$ is Borel-measurable given any shock realization Z and Borel-measurable entry profile F', and $F(x') = 1$, then the revenues of the producer at x' choosing the action a' satisfy*

$$S \times r\left(a', x'; A, Z, F\right) = S \times \rho\left(a', x'; G\left(A, Z, F\right), Z, N_F\right),$$

where $N_F \equiv \mu(M)$ is the mass of producers operating and

$$G\left(A, Z, F\right)\left(a'\right) \equiv \frac{1}{N_F} \int_{\mathcal{X}} I\left\{A\left(x; Z, F\right) \leq a'\right\} \times F(x) d\mu\left(x\right).$$

Two aspects of Assumption A1 capture the idea that producers compete atomistically. First, a producer's revenues only depend on its own choices, aggregate shocks, the mass of competing producers, and the empirical distribution of their actions. Second, any one producer has measure zero when computing this distribution, so changing a single producer's conduct alters no other producer's revenue. The example revenue function above clearly satisfies Assumption A1. In any particular industry, the number of producers is obviously countable and not continuous. Models of atomistic competition are of empirical interest because their predictions might fit the data well in spite of the false simplifying assumption of a continuum of producers.

Assumption A2 (Product Differentiation) *If $F(x') \geq 2$ and A satisfies condition (a) of the definition of a free-entry equilibrium, then $\pi(x'; A, F, S) < 0$.*

Assumption A2 states that competition between producers of identical products is tough enough to guarantee that no more than one producer will occupy any location in $\mathcal{X}$. Thus, the observed market structure will not contain any "local" oligopolies. The specific example satisfies this assumption.

2.4 Intrinsic Scale Effects

Thus far, the model's specification does not rule out direct effects of the scale of the market, measured with either S or N_F, on producers' revenues or costs. For example, the product space might be limited so that entry cannot continue indefinitely. The market shares of producers with particular choices of x might be more or less sensitive to the size of the market, or directly raising S could systematically reduce costs and so encourage entry and production. For all of these reasons, the distribution of producers' decisions across large and small markets could differ. The following three conditions eliminate them as a theoretical possibility.

Assumption S1 (Invariance of Market Shares) *The per consumer revenue function* $\rho(\cdot)$ *is homogeneous of degree -1 in* N_F.

Assumption S1 is closely related to the independence of irrelevant alternatives: Adding a producer to a market does not change the relative market shares of any two incumbents. It also rules out Sutton's (1991) assumption that the winner of a pre-entry investment game obtains a minimum share of market sales, so his analysis of natural oligopolies does not apply here. In the example, Assumption S1 follows from the assumption that consumers match uniformly with firms.

Assumption S2 (No Productive Spillovers) *For any entry choice* $x' \in \mathcal{X}$,*action* $a' \in \mathcal{A}$, *and any two strategy profiles* (A, F), $(A^{\star}, F^{\star})$ *and market sizes* S *and* $S^{\star}$, *if*

$$c(a', x'; A, Z, F, S) < c(a', x'; A^{\star}, Z, F^{\star}, S^{\star})$$

then

$$S \times r(a', x'; A, Z, F) < S^{\star} \times r(a', x'; A^{\star}, Z, F^{\star})$$

Assumption S2 implies that is impossible to hold a producer's choices of x and a fixed, change its competitive environment, and lower that producer's costs without simultaneously lowering its revenues. If producers choose their prices, then Assumption S2 immediately implies that a producer's costs cannot fall unless the production of at least one good also falls. The simple affine technology of the example obviously satisfies Assumption S2.

Assumption S3 (Distinct Observationally Equivalent Strategy Profiles) *For any market size* S *and strategy profile* (A, F) *such that* $F(x) \leq 1$ *for all* $x \in \mathcal{X}$, *there exists a continuous, one to one, and onto function* $g : \mathcal{X} \to \mathcal{X}$ *such that if we define* $F^T(x) \equiv F(g^{-1}(x))$, *and* $A^T(x; Z, F^T) = A(g^{-1}(x), Z, F)$ *then*

(a) $\forall x \in \mathcal{X},\ F(x) + F^T(x) \leq 1$;

(b) if $F(x') > 0$*, then*

$$S \times r(a', x'; A, Z, F) = S \times r\left(a', g(x'); A^T, Z, F^T\right)$$

and

$$c(a', x'; A, Z, F, S) = c\left(a', g(x'); A^T, Z, F^T, S\right);$$

(c) $\forall M \in \mathcal{M}$, $\mu\left(g^{-1}(M)\right) = \mu(M)$.

In many models of competition with product differentiation, it is possible to rearrange producers' locations in $\mathcal{X}$, hold their actions fixed, and leave their payoffs unchanged. In Assumption S3, conditions *(a)* and *(b)* require such a rearrangement to be possible for any given strategy profile. In the example, $\mathcal{X}$ is an infinite set of all possible products without any spatial structure or asymmetries in demand or cost, so such a rearrangement is possible. Condition *(c)* requires $g(x)$ to be measure preserving, so that the rearrangement does not alter the mass of producers. Overall, Assumption S3 asserts that no location in $\mathcal{X}$ has payoff-relevant characteristics that are unique.

2.5 Equilibrium

The following two conditions ensure that potential entrants' expectations about post-entry competition can be well-defined and that a free-entry equilibrium exists.

Assumption E1 (Existence of Nash Equilibrium) *For any market size* S*, there exists a strategy profile* $A(x, Z, F)$ *that satisfies condition (a) of the definition of a free-entry equilibrium.*

Assumption E2 (Existence of a Measurable Free Entry Equilibrium) *There exists a market size* $S_0 > 0$ *with a corresponding free-entry equilibrium* (A_0, F_0) *such that*

(a) $F_0(x)$ *and* $A_0(x; Z, F_0)$ *are Borel measurable functions of* x *for any* Z*, and*

(b) $A_0(x'; Z, F) = A_0(x'; Z, F_0)$ *if* $F(x') = F_0(x') = 1$ *and* $F(x) = F_0(x)$ *almost everywhere.*

To the extent that nearly all existing models of entry and competition have well-defined equilibria, assumption E1 and part (a) of Assumption E2 can be viewed as regularity conditions. Part (b) of Assumption E2 eliminates the possibility that a positive measure of firms respond to equilibrium deviations by a single (measure zero) firm. Both assumptions are clearly true for the specific example.

2.6 Market Size and Producers' Actions

The above assumptions place sufficient structure on the model to imply the following observational implication of atomistic competition.

Proposition *If* $S = 2^j \times S_0$*, where* j *is a non-negative integer and* S_0 *is defined in Assumption E2, then there exists a free entry equilibrium* (A_j, F_j) *such that*

$$G(A_j, Z, F_j) = G(A_0, Z, F_0)$$

where (A_0, F_0) *is the free-entry equilibrium assumed to exist in Assumption E2.*

The appendix presents the proposition's proof. Here, I only outline the argument. Consider the free-entry equilibrium (A_0, F_0) for S_0. We know from Assumption S3 that there is a different but observationally equivalent strategy profile, $\left(A_0^T, F_0^T\right)$. Now consider a market with $S_1 = 2 \times S_0$ and entry profile, $F_0 + F_0^T$. If all producers duplicate the actions they take in the smaller market, then the empirical *c.d.f.* of producers actions remains unchanged, so Assumptions A1, S1, and S2 imply that each producer's profit maximizing action remains unchanged. That is, the action profile that duplicates producers' actions is a Nash equilibrium profile for this larger market size and entry profile. Each producer's profits remain unchanged, and the profits from producing in an unoccupied location in $\mathcal{X}$ are identical to their value in the original free entry equilibrium with the smaller market size, so conditions

(b) and (c) of the definition are satisfied. Each producer's actions equal those from the original equilibrium, so their empirical distributions are also unchanged as the proposition asserts.[4]

2.7 Extensions

The proposition illustrates that the invariance of producers' decisions to the market's size in the specific example extends well beyond its particular assumptions. Nevertheless, the general model is restrictive in two ways that are worth noting. First, it has no role for actions that are taken prior to the realization of Z that do not directly differentiate firms' products, such as investments that increase the likelihood of having a high quality restaurant. Adding such pre competition actions to the general model increases its notational burden but does not alter its scale invariance. Second, the use of the Borel integral to form the *c.d.f.* of producers' actions in Assumption A1 restricts product placement decisions to be continuous choices. Scale invariance requires *some* continuous product placement decision to differentiate firms' products, but it does not require all product placement decisions to be continuous. Extending the general model to allow for discrete product placement decisions is straightforward.

2.8 Atomistic and Monopolistic Competition

Before proceeding to test the atomistic competition model's predictions, it is helpful to clarify the relationship between what I have labelled "atomistic competition" with the large theoretical literature on monopolistic competition. For some authors, "monopolistic compe-

[4]The proposition's focus on doubling market size can easily be changed if the assertion that $g(x)$ is measure preserving in Assumption S3 is replaced with the assumption that for any $t > 1$, there exists a $g_t(x)$ satisfying the assumption's other conditions and which satisfies $\mu(g_t^{-1}(M)) = t \times \mu(M)$. With this, a parallel argument establishes that a free-entry equilibrium that replicates producers' decisions exists for any market size greater than S_0.

tition" refers to all imperfect competition among a large number of producers. Models that prominently feature strategic interaction, such as Salop's (1979) model of spatial competition, then go by the label of "Hotelling-style" monopolistic competition. Models with only trivial strategic considerations, such as Spence's (1976) are called "Chamberlin-style".

Hart (1985) and Wolinsky (1986) propose a more exclusive definition of "monopolistic competition" based on four criteria.

> (1) there are many firms producing differentiated commodities; (2) each firm is negligible in the sense that it can ignore its impact on, and hence reactions from, other firms; (3) each firm faces a downward sloping demand curve and hence the equilibrium price exceeds marginal cost; (4) free entry results in zero-profit of operating firms (or, at least, of marginal firms).[5]

These clearly correspond to what others call Chamberlin-style monopolistic competition. Hart and Wolinsky's first two criteria correspond to Assumptions A2 and A1, and the fourth criterion is implicit in the definition of a free-entry equilibrium. The definition of atomistic competition does not require firms to face downward sloping demand curves, but it clearly allows for that possibility. Hence, models of monopolistic competition (in the sense of Hart and Wolinsky) can usually be written without economically substantial changes to satisfy the assumptions this paper places on atomistic competition. However, the definition of atomistic competition is broad enough to also encompass models without market power.

3 Competition among Restaurants

In this section, I examine whether or not atomistic competition describes U.S. cities' restaurant markets well. The analysis closely follows that of Campbell and Hopenhayn (2005). For thirteen retail trade industries in a sample of 224 Metropolitan Statistical Areas (*MSA*s), they estimate the influence of market size on establishments' average sales and employment.

[5] Wolinsky (1986), page 493.

They find that more populous *MSA*s have larger restaurants, even after controlling for factor prices and customer demographics. In this paper, I use observations of restaurants' seating capacities, pricing decisions, and exit rates from the 1992 *Census of Retail Trade* for the same sample of *MSA*s. The volume RC92-S-4, "Miscellaneous Subjects", reports the number of restaurants operating at any time during 1992 and at the end of that year. These observations immediately yield one measure of the annual exit rate. This volume also reports restaurants' average seating capacities for each *MSA* as well as the fraction of restaurants with typical meal prices greater than \$5.00, \$7.00, and \$10.00.

Table 1 reports summary statistics for these five measures of restaurateurs' actions for the 224 sample *MSA*s. Consider first the three summary statistics from the distribution of prices. In the average *MSA* two thirds of restaurants have prices greater than \$5.00, and approximately one third have a typical meal price greater than \$7.00. The standard deviations of these fractions across *MSA*s are all approximately 13 percent, and all three of these fractions are positively correlated with *MSA* population. That is, the raw correlation between restaurant prices and *MSA* population is positive. The exit rate in the average *MSA* is 10.7 percent, its standard deviation across *MSA*s is 3 percent, and it is moderately negatively correlated with *MSA* population. The average *MSA* has an average restaurant seating capacity of approximately 100 seats. This varies substantially across *MSA*s and is only modestly positively correlated with population.

3.1 Regression Results

Let Y_i denote the value of one of these five summary statistics of restaurateurs' actions for *MSA* i, and use S_i and W_i to represent that *MSA*'s population and a vector of control variables that includes relevant factor prices and consumer demographics. The factor prices account for larger cities' higher cost of commercial space and wages and lower cost of advertising per consumer exposure. The demographic variables control for differences in preferences associated with income, race, and education that could shift the the nature of producers' products and thereby indirectly influence their observable decisions. These control variables are identical to those used in Campbell and Hopenhayn (2005). The regression of Y_i on $\ln S_i$ and W_i is

$$Y_i = m(\ln S_i, W_i) + U_i.$$

Here, $m(\cdot)$ is not restricted to a particular functional form. If the restaurant markets are atomistically competitive and the control variables in W_i adequately account for systematic differences across markets in consumer preferences and production technology that are correlated with market size, then $\partial m(\ln S, W)/\partial \ln S = 0$.[6]

The curse of dimensionality makes the estimation of $m(\ln S, W)$ infeasible. However, it is still possible to test the hypothesis that its dependence on $\ln S$ is trivial using estimates of the regression function's density weighted average derivatives. These are

$$\begin{aligned} \delta_S &\equiv \mathbf{E}\left[\frac{\partial m\left(S,W\right)}{\partial \ln S} f\left(\ln S, W\right)\right] / \mathbf{E}\left[f\left(\ln S, W\right)\right] \\ \delta_W &\equiv \mathbf{E}\left[\frac{\partial m\left(S,W\right)}{\partial W} f\left(\ln S, W\right)\right] / \mathbf{E}\left[f\left(\ln S, W\right)\right], \end{aligned} \tag{1}$$

where $f(\ln S, W)$ is the joint density function of $\ln S$ and W across markets and expectations are taken with respect to the same joint density function. Powell, Stock, and Stoker (1989) provide a simple instrumental variables estimator of δ_S and δ_W which converges to the true parameter values at the parametric rate of $\sqrt{N}$. Under atomistic competition, $\delta_S = 0$, so its estimation provides one means of testing the model without imposing undue parametric restrictions.

For the five measures of restaurateurs' actions, Table 2 reports the estimated values of δ_S and δ_W along with consistent estimates of their asymptotic standard errors. Before estimation, $\ln S$ and W were scaled by their standard deviations, so the coefficients have an interpretation as the average response of the dependent variable to a one-standard-deviation increase in the regressor. The estimates indicate that restaurant industries in larger cities

[6]Although the general model does not include market-specific variables that shift either the revenue or cost functions, such as factor prices and consumer demographics, adding them is straightforward.

charge lower prices, exit less frequently, and have larger average seating capacity. The fraction of restaurants with prices greater than \$5.00 declines with population, while population's influence on the fractions with prices greater than \$7.00 and \$10.00 is small and statistically insignificant. Increasing the population by one standard deviation – approximately 90 percent for this sample of *MSA*s – deceases the exit rate (on average) by 0.69 percentage points and increases average seating capacity by 1.86 percent. These coefficients are statistically significant at every conventional size.[7]

3.2 Why does Market Size Matter?

The estimates of δ_S indicate that the model's prediction of size invariance does not hold good for U.S. restaurants, so this industry violates at least one of the model's assumptions. The nature of the proposition and the specific details of the estimation together suggest that that either the assumption that producers compete anonymously (Assumption A1) or the assumption that head-to-head competition at the same location in $\mathcal{X}$ is unprofitable (Assumption A2) are among those assumptions that are violated. That is, the rejection of the proposition's prediction reflects violations of the two economically interesting assumptions rather than the inappropriate application of the regularity conditions.

I develop this argument in two steps. First, I present theoretical or empirical reasons to maintain Assumptions E1, E2, S2, and S3. Then I assert that an economically interesting

[7]Powell, Stock, and Stoker's estimator requires a first-stage nonparametric estimation of $\partial f(\ln S, W)/\partial \ln S$ and $\partial f(\ln S, W)/\partial W$. The estimates reported here are based on the tenth-order bias-reducing kernel of Bierens (1987) and use a bandwidth equal to 2. These choices do not impact the estimates' asymptotic distribution, but they could influence their realization in any given sample. The conclusion that $\delta_S = 0$ in the regressions of the fraction of restaurants with prices greater than \$7.00 and \$10.00 *is* sensitive to the bandwidth choice. If the bandwidth equals 3, then the estimates of δ_S are small, negative, and statistically significant. If it equals one instead, the estimates are positive and statistically significant, indicating that prices are more dispersed in larger markets. The estimates of δ_S for the other three dependent variables are robust to these bandwidth changes.

violation of the single remaining assumption (S1) implies that Assumption A1 also does not hold good.

Begin with the conditions that ensure the existence of *some* equilibrium (Assumptions E1 and E2). If they are false, then the game-theoretic approach to industry dynamics is itself inappropriate. In this sense, these assumptions are regularity conditions that any reasonable model of the U.S. restaurant industry must satisfy. Assumption S3 asserts that there is no location in $\mathcal{X}$ with unique payoff-relevant characteristics. Many models that feature strategic interaction, such as Salop's (1979) model of competition on the circle, satisfy this assumption. For this reason, I also treat this assumption as a regularity condition.

Next, consider Assumption S2, which requires that changing market size does not impact production technology. Productive spillovers from urbanization provide one possible reason for this assumption to fail. To examine this, I have estimated the density-weighted average derivatives after including the measure of productive spillovers that Glaser, Kallal, Scheinkman, and Schleifer (1992) found to be the most useful in forecasting a city's wage growth - the share of an *MSA*'s employment concentrated in its five largest two-digit industries. The only substantial difference between the resulting estimates of δ_S with those reported in Table 2 occurs in the regression of the fraction of restaurants with prices greater than \$10. The estimate of δ_S rises from 0.15 to 0.25 and becomes statistically significant at the 5% level. Hence, it appears to be unlikely that the nonzero estimates of δ_S reflect productive spillovers.

The final assumption to consider is S1. Arguing that it must hold good is pointless, because many interesting theories of non-atomistic competition rely on its violation. However, the present argument requires only that if it does not hold for economically interesting reasons, then neither does Assumption A1.

Assumption S1 essentially asserts the independence of irrelevant alternatives for the case where all producers occupy distinct locations in the product space. This naturally follows from models of random utility in which a consumer's utility from any two firms' goods are mutually independent. When this condition does not hold, then a consumer who most prefers one firm's good is likely to consider a specific second firm's good as her next best choice. In that case, the two firms interact strategically. Denekere and Rothschild (1992) provide a general random utility model that exemplifies this point. They show that a form of dependence across a given consumer's benefits from purchasing different firms' goods generates the model of competition on the circle. I conclude from this that economically interesting violations of S1 lead to strategic interaction, which violates Assumption A1.

If the above points are taken as given, then the data lead to the logical conclusion that either Assumption A1 or Assumption A2 does not hold good in the U.S. restaurant industry. In either case, strategic considerations influence restaurateurs' conduct.

4 Related Literature

Structure-conduct-performance studies gave rise to many examinations of competitive outcomes' dependence on market size. One strand of this literature uses the empirical relationship between market size and the number of competitors to infer how adding competition lowers markups. If doubling market size leads to a less than proportional increase in the number of producers, either per-consumer profits fall with entry or incumbents raise entrants' fixed costs. Bresnahan and Reiss (1989) apply this identification strategy to concentrated retail automobile markets in isolated towns. Berry and Waldfogel (2003) examine the influence of market size on the number of competitors in a slightly broader sample of *MSA*s than that used in this paper, and they find that the number of restaurants increases less than proportionally with *MSA* population.[8] The proof of this paper's proposition makes it clear that the number of producers in atomistically competitive markets is proportional to the number of consumers, so Berry and Waldfogel's finding reinforces this paper's empirical

[8]See the third and fourth columns of their Table 3.

conclusion.[9]

This paper's proposition does not stress the relationship between market size and the number of firms under atomistic competition, because a finding that doubling market size less than doubles the number of firms could arise solely from measurement error in market size. Measurement error could make the rejection of this paper's exclusion restrictions less likely when they are false, but it does not lead directly to their rejection when they are true. In this sense, a test of atomistic competition based on the relationship between noisily measured market size and measures of producer actions is conservative.[10]

This paper derives testable predictions of a free-entry model without the use of parametric assumptions. In this respect, Sutton's (1991) analysis of models with endogenous sunk costs precedes it. He considers a model of competition in which entrants compete with sunk investments in product quality. The firm with the greatest investment earns a guaranteed minimum market share, regardless of the number of other producers. Sutton shows that these features together imply a nonparametric upper bound on the number of entrants, and he demonstrates that cross-country data from several advertising-intensive food processing industries satisfy this bound. As the number of consumers grows, the number of entrants remains bounded from above. In this sense, industries that satisfy his model's assumptions are natural oligopolies. As noted above in Subsection 2.7, it is notationally burdensome but straightforward to add pre-entry investments in quality to this paper's model. This extension leaves the model's nonparametric testable implications unaltered. In particular,

[9] Berry and Waldfogel's finding also manifests itself in the observations used in the present paper. The estimate of δ_s from a nonparametric regression of the number of restaurants' logarithm on population's logarithm and the other control variables listed in Table 2 using Campbell and Hopenhayn's (2005) sample of *MSA*s equals 0.8, and this is significantly different from one.

[10] Bresnahan and Reiss (1989) can measure market size accurately because they carefully chose their sample towns. This strategy becomes infeasible when considering competition in large markets in which the definition of the market and industry are themselves somewhat subjective, so prudence requires accounting for possible measurement error.

the number of producers grows linearly with market size. The contrast between that result and Sutton's highlights the role of endogenous sunk costs in his results: They are necessary but not sufficient for an industry to be a natural oligopoly. Hence, the simple observation that an industry's producers incur endogenous sunk costs does not imply that its firms are oligopolists. However, tests of the exclusion restrictions from atomistic competition do provide information about the nature of competition.

The analysis of the exit of restaurants places this paper in another vast literature which examines the rate of producer turnover and the reallocation of resources between producers. These papers have focused on differences in firm growth and survival across the life cycle (as in Dunne, Roberts, and Samuelson (1989)) and on the interaction of resource reallocation with the business cycle (as in Davis, Haltiwanger, and Schuh (1996), Campbell (1998), and Campbell and Lapham (2004)). Analysis of how the pace of resource reallocation varies with local market conditions, similar to that in this paper, is much scarcer. Syverson (2004) shows that ready-mixed concrete producers serving geographically concentrated markets have higher average productivity and less productivity dispersion than their counterparts is more sparsely populated areas, and he interprets this as the result of more intense selection in highly competitive markets. Abbring and Campbell (2004a) find the opposite to be true. They examine the reallocation of alcohol sales across Texas restaurants, and they find that it occurs more slowly in less concentrated local markets. This is consistent with this paper's finding that the restaurants' exit rate is lower in larger *MSA*s. In light of this paper's theoretical results, this observation suggests that strategic interaction substantially influences the rate of restaurant turnover. However, Syverson's results indicate that much more work is required before a robust stylized fact about the relationship between industry concentration and reallocation emerges.

5 Conclusion

The relative simplicity of atomistic competition models makes them an appealing first choice for the empirical study of competition in large markets. This paper presents nonparametric testable implications from them which can be used to examine the suitability of that approach before proceeding with a more involved investigation.[11] The application of these results to observations of U.S. restaurants' prices, seating capacity, and exit rates indicates that atomistic competition does not appear to be a promising approach to better understanding this industry. Relatedly, Campbell and Hopenhayn (2005) find that restaurants serving larger markets are themselves larger; and Yeap (2005) documents that this increase in average size reflects only the decisions of firms owning two or more restaurants. Taken together these findings indicate that better understanding of competition among restaurants in large markets requires confronting restaurateurs' strategic behavior.

[11]For example, Abbring and Campbell (2004b) apply this papers' results to test the assumption of atomistic competition in their structural model of new Texas bars' growth and exit decisions.

Proof of the Proposition

Clearly, the proposition is true for $j = 0$. We now wish to show that it is true for $j = 1$. The proposition can then be demonstrated recursively for greater values of j.

Let $g(x)$ be the function assumed to exist in Assumption S3. Define the entry profile $F_1(x) = F_0(x) + F_0^T(x)$, where the latter entry profile is defined as in the statement of Assumption S3. From Assumption A2 and the definition of a free-entry equilibrium, we know that $F_0(x) \in \{0, 1\}$. Therefore, condition (a) of Assumption S3 ensures that $F_1(x) \in \{0, 1\}$.

We know from Assumption E1 that there exists an action profile $A(x; Z, F)$ that satisfies condition (a) of a free-entry equilibrium's definition for $S_1 = 2 \times S_0$. We now wish to use this and $A_0(x; Z, F)$ to construct an action profile that forms a candidate free-entry equilibrium when paired with F_1. For any entry profile $F(x)$ such that either $F(x') \geq 2$ for some $x' \in \mathcal{X}$ or $\{x | F(x) \neq F_1(x)\}$ is either not measurable or has positive measure, define $A_1(x; Z, F) = A(x; Z, F)$.

For any entry profile $F(x) \in \{0, 1\}$ for which $F(x) = F_1(x)$ almost everywhere, there exists two measurable sets C_p and C_m with $\mu(C_p) = \mu(C_m) = 0$ and $F(x) = F_1(x) + I\{x \in C_p\} - I\{x \in C_m\}$. Define $F_0(C_p)(x) = F_0(x) + I\{x \in C_p\}$. If $F(x) = 1$, then either $F_0(C_p)(x) = 1$ or $F_0^T(x) = 1$. Therefore, we can define the action profile for these values of x with

$$A_1(x; Z, F) = \begin{cases} A_0(x; Z, F_0(C_p)) & \text{if } F_0(C_p)(x) = 1, \\ A_0(g^{-1}(x); Z, F_0(C_p)) & \text{otherwise.} \end{cases}$$

Because the composition of Borel measurable functions is itself Borel measurable, $A_1(x; Z, F)$ is a Borel measurable function of x.

The next step is to show that (A_1, F_1) is a free-entry equilibrium. To do so, consider the definition's three conditions in turn.

Condition *(a)*

Note that by construction $A_1(x; Z, F)$ satisfies the inequality in condition (a) of a free-entry equilibrium's definition if $F(x) \geq 2$ for some $x \in \mathcal{X}$ or $\{x|F(x) \neq F_1(x)\}$ is either not measurable or has positive measure. Suppose that $F(x) \in \{0, 1\}$ and $F(x) = F_1(x)$ almost everywhere. This implies

$$\begin{aligned} G(A_1, Z, F)(a') &\equiv \frac{1}{N_F} \int_{\mathcal{X}} I\{A_1(x; Z, F) \leq a'\} F(x) \, d\mu(x) \\ &= \frac{1}{2} \frac{1}{N_{F_0(C_p)}} \int_{\mathcal{X}} I\{A_0(x; Z, F_0(C_p)) \leq a'\} F_0(C_p)(x) \, d\mu(x) \\ &+ \frac{1}{2} \frac{1}{N_{F_0^T}} \int_{\mathcal{X}} I\left\{A_0\left(g^{-1}(x); Z, F_0(C_p)\right) \leq a'\right\} F_0^T(x) \, d\mu(x) \\ &= G(A_0, Z, F_0(C_p))(a'). \end{aligned}$$

The first equality holds because F_1 and $F_0(C_p) + F_0'(C_p)$ differ by a set of measure zero, and the last equality follows from Proposition 1 in Chapter 15 of Royden (1988).

With this and Assumptions A1 and S1, we can conclude that if $F_0(C_p)(x) = 1$, then for all $a' \in \mathcal{A}$, $S_1 \times \rho(a', x'; G(A_1, Z, F), Z, N_F) = S_0 \times \rho\left(a';, x';, G(A_0, Z, F_0(C_p)), Z, N_{F_0(C_p)}\right)$ In turn, this and Assumption S2 imply that

$$\text{(A.1)} \quad \begin{aligned} &S_1 \times \rho(a', x'; G(A_1, F), Z, N_F) - c(a', x'; A_1, Z, F, S_1) \\ &= S_0 \times \rho\left(a';, x';, G(A_0, F_0(C_p)), Z, N_{F_0(C_p)}\right) - c(a', x'; A_0, Z, F_0(C_p), S_0) \end{aligned}$$

The action $A_0(x'; Z, F_0(C_p)) = A_1(x'; Z, F)$ maximizes the right-hand side of (A.1), so it must also maximize its left-hand side.

Alternatively, if $F_0'(C_p)(x) = 1$, then we can construct a parallel argument to show that $A_1(x', F)$ maximizes the firm's profit. Thus $A_1(x, F)$ satisfies condition (a) of a free-entry equilibrium's definition.

Condition (b)

Next, consider condition (b) of the definition. Extending the notation above, denote $F_1(x) + I\{x = x'\}$ with $F_1(\{x'\})(x)$, If $F_1(x') = 1$, then the definition of A_1 and Assumptions

A2 and E1 imply that $\pi\left(x';A_1,F_1\left(\{x'\}\right),S\right)\leq 0$. Next, note that if $F_1\left(x'\right)=0$, then we know from above that $G\left(A_1,Z,F_1\left(\{x'\}\right)\right)(a)=G\left(A_0,Z,F_0\left(\{x'\}\right)\right)(a)$, and that $N_{F_1(\{x'\})}=2\times N_{F_0(\{x'\})}$. Therefore, Assumptions A1, S1, and S2 and the definition of a free-entry equilibrium imply that $\pi\left(x';A_1,F_1\left(\{x'\}\right),S\right)\leq 0$ in this case as well. Hence, condition (b) of the definition is satisfied.

Condition (c)

Finally, consider condition (c) of a free-entry equilibrium's definition. Because $G\left(A_1,Z,F_1\right)(a)=G\left(A_0,Z,F_0\right)(a)$ and $N_{F_1}=2\times N_{F_0}$, we know that if $F_0\left(x'\right)=1$ then $\pi\left(x';A_1,F_1,S_1\right)=\pi\left(x';A_0,F_0,S_0\right)\geq 0$ Furthermore, conditions (b) and (c) of Assumption S3 imply that this inequality also applies if $F_0^T\left(x'\right)=1$. Therefore, the first inequality in condition (c) of the definition holds good.

The second inequality in this condition holds trivially from Assumption A2 and the definition of A_1 if $F_1\left(x''\right)=1$. Suppose instead that $F_1\left(x''\right)=0$ and $F_1\left(x'\right)=1$. We know that $F_1(x)+I\left\{x=x''\right\}-I\left\{x=x'\right\}=F_1(x)+I\left\{x=x''\right\}$ almost everywhere. From this and the fact that we have already verified condition (b) of an equilibrium's definition, we conclude that

$$\pi\left(x'';A_1,F_1+I\left\{x=x''\right\}-I\left\{x=x'\right\},S_1\right)\leq 0.$$

Thus, the second inequality of condition (c) holds and $\left(A_1,F_1\right)$ is a free-entry equilibrium.

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Table 1: Summary Statistics[i]

	Average	Standard Deviation	Correlation with Population[ii]
$\mathbb{S}(\$5.00)$	66.19	13.57	0.10
$\mathbb{S}(\$7.00)$	35.34	13.92	0.25
$\mathbb{S}(\$10.00)$	17.03	10.78	0.22
Exit Rate	10.70	3.16	-0.12
Average Seating Capacity	98.97	22.83	0.08

Notes: (i) In the table, $\mathbb{S}(\$x)$ refers to the fraction of restaurants in an *MSA* with typical meal prices greater than or equal to $\$x$. These fractions and the exit rate are expressed in percentage points. (ii) The reported correlations are between the given variable and population's logarithm. For Average Seating Capacity, the reported correlation is between the logarithm of both variables. See the text for further details.

Table 2: Nonparametric Regression Estimates[i,ii]

	$\mathbb{S}(\$5.00)$	$\mathbb{S}(\$7.00)$	$\mathbb{S}(\$10.00)$	Exit Rate	Log Average Seating Capacity
Population	-2.07***	0.13	0.15	-0.69***	1.86***
	(0.16)	(0.15)	(0.11)	(0.04)	(0.24)
Commercial Rent	2.28***	2.74***	1.42***	-0.26***	-1.67***
	(0.15)	(0.13)	(0.10)	(0.04)	(0.22)
Retail Wage	2.62***	1.13***	-0.27**	0.61***	-2.24***
	(0.17)	(0.17)	(0.13)	(0.04)	(0.27)
Advertising Cost	-1.89***	-1.08***	-0.92***	-0.26***	-0.16
	(0.12)	(0.12)	(0.11)	(0.03)	(0.23)
Income	-0.37**	1.84***	2.20***	-0.55***	4.07***
	(0.19)	(0.18)	(0.13)	(0.04)	(0.30)
Percent Black	3.36***	1.75***	1.79***	0.57***	-3.44***
	(0.13)	(0.12)	(0.08)	(0.03)	(0.25)
Percent College	2.97***	2.14***	1.08***	0.01	1.91***
	(0.15)	(0.13)	(0.10)	(0.04)	(0.23)
Vehicle Ownership	-0.55***	-2.34***	-1.60***	-0.51***	1.42***
	(0.13)	(0.12)	(0.10)	(0.03)	(0.25)

Notes: (i) The table reports estimates of density-weighted average derivatives from the regressions of the indicated variables on the regressors listed in the first column. Asymptotic standard errors appear below each estimate in parentheses. The superscripts $\star$, $\star\star$, and $\star\star\star$ indicate statistical significance at the 10, 5, and 1 percent levels (ii) In the table, $\mathbb{S}(\$x)$ refers to the fraction of restaurants in an *MSA* with typical meal prices greater than or equal to $\$x$. See the text for further details.