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Experience Advantages and Entry Dynamics

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We consider an extension of Dixit and Shapiro's model of uncoordinated entry dynamics to the case when there are experience advantages: each firm's payoff from being in the market increases with past experience, measured by the number of periods it has previously been active. We select an equilibrium which satisfies a number of reasonable properties and provide the exact bounds for the long-run number of active firms, which is a random variable. These bounds correspond to generalized *no entry–no exit conditions*. *Journal of Economic Literature* Classification Number: L10. © 1993 Academic Press, Inc.

1. INTRODUCTION

Traditional industrial organization holds that there is a causal relationship between market structure, firm conduct, and market performance (cf. [3]). More recent theories have attempted to extend this paradigm by considering market structure itself as an endogenous variable (cf. [6], and references therein). In this paper, we present a model of entry into a new market which explains the endogenous formation of market structure.

Our model has two distinguishing features. First, we assume there are experience advantages: each firm's payoff is an increasing function of its experience, as measured by the number of periods it has been active. That is, firms which have previously been in the market have an advantage relative to newcomers; and firms which have been in the market for longer have an advantage relative to firms with less experience. One can argue that this is a fairly pervasive phenomenon (cf. [9]). Sunk costs are perhaps the simplest instance of experience advantages (cf. [27]). Another example arises from product differentiation advantages of pioneering brands (cf. [25]). Still another example is given by cost-reducing learning-by-doing, insofar as age is a good measure of a firm's experience (cf. [1]).

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The second important assumption of our model is that entry is an uncoordinated process. The previous literature has typically considered the case of sequential entry (cf. [6, 20, 22, 26]). This is a somewhat extreme framework, for arbitrating an artificial order of entry amounts to assuming a "considerable feat of coordination" [7, p. 34].[1] In our model, we treat potential entrants symmetrically, assuming that entry decisions are simultaneous. This is also a somewhat extreme framework, for it assumes there is very little coordination. However, we believe it to be a more useful benchmark, especially in the case of entry into a new market.[2]

Since entry decisions are simultaneous and information about competitors is imperfect, entry mistakes (i.e., excessive or insufficient entry) occur with positive probability. This aspect was considered by Dixit and Shapiro [4]. Implicit in their model is the fact that when entry costs are almost fully recoverable, there exists a dynamic equilibrium in which, by means of successive entry and exit, the number of active firms converges to n, the equilibrium number of active firms in the static entry game. This result is important for two reasons. First, it provides a mechanism for selecting among the multiple pure-strategy equilibria of the static game. Second, it shows that, absent experience advantages, entry mistakes are irrelevant in terms of the long-run market structure (i.e., the number of active firms).

Our model extends Dixit and Shapiro's. We show that in the presence of experience advantages, entry mistakes may be "irreversible." The equilibrium number of active firms at time t, X_t, converges with probability one, as in the above example. However, the limit point of X_t is a non-degenerate random variable, i.e., X_t may converge to different values with positive probability. As a result, despite the fact we select a single equilibrium, the long-run outcome is non-unique (a random variable, to be more precise).[3]

Our results provide the exact bounds of the limit set of X_t. These can be seen as a generalization of the usual no entry–no exit conditions $\Pi(n) \geqslant 0 \geqslant \Pi(n+1)$, which are obtained in the static, coordinated entry model.

[1] That is, assuming sequential entry into a new market abstracts from the problem of entry coordination, or the "nomination problem," to use Richardson's [24] terminology. Suppose there are N potential entrants and that $n < N$ is the maximum number of firms the market can accommodate. Then, it is a Nash equilibrium for n firms to enter and the remaining $N-n$ to stay out. This leads to $\binom{N}{n}$ possible equilibria in pure strategies. One should therefore be clear about the mechanism which "nominates" n firms to enter.

[2] In contrast with models of entry into a new market, models of entry deterrence start from an initial asymmetric situation in which there is an incumbent firm and a potential entrant. In this case, the Stackelberg assumption (with the incumbent moving first) seems more reasonable. See [9] and references therein.

[3] For a similar result in a different context, see [2].

2. Main Results

In this section, we present the basic model and the main results concerning the time path of the equilibrium market structure.

We consider an industry with N potential, identical firms and a sequence of periods $t = 1, ...$. At the beginnig of each period t, all firms simultaneously decide whether to enter the market or not. (We will designate these actions by "in" and "out," respectively.) The central feature of our model is that firms gain from experience, i.e., each firm's payoff from being in the market depends on its own and on the other firms' past experience. Firm i's index of experience is assumed to be given by the number of periods it has previously been active.

We restrict attention to cases when firms play Markov strategies, where a state is defined by the experience level of each firm. As a result, the only decisions at time t which affect future payoffs are entry decisions, and thus, once entry decisions have been made for period t, that period's payoffs result from the play of a one-shot game, which we assume has a well-defined equilibrium. This equilibrium is summarized by the function Π, which gives each firm's equilibrium payoffs. Specifically, the one-period payoff for firm i is given by $\Pi(n, l_i, l_{-i})$, where n is the number of active firms (including firm i), l_i is firm i's experience level, and $l_{-i} = (l_1, ..., l_{i-1}, l_{i+1}, ..., l_N)$ is the vector of the remaining firms' experience levels. Without loss of generality, we suppose firms are ordered by level of experience.[4]

We make the following assumptions regarding the function $\Pi(\cdot)$:

Assumption 1. *$\Pi(n, l_i, l_{-i})$ is strictly decreasing in n.*

Similar assumptions in "reduced-form" models appear in [4, 19]. Notice that we exclude extreme cases like Bertrand competition with a homogeneous good and constant marginal costs, since we require Π to be *strictly* decreasing in n.

Assumption 2. *$\Pi(n, l_i, l_{-i})$ is non-decreasing in l_i.*

This is a central assumption. It means that there exist experience advantages. Notice we do not require Π to be strictly increasing in l_i. A model with entry sunk costs (and no other source of experience advantages) would satisfy Assumption 1. In that case, we would have $\Pi(n, l_i, l_{-i})$

[4] Implicitly, we are assuming firms are anonymous. We could also have opted for the (somewhat more complicated) notation $\Pi(I_{N-1}, l_i, l_{-i})$, where I_{n-1} is a $(N-1)$-dimensional vector of indicator variables ($I_j = 1$ if firm j is active, $I_j = 0$ otherwise). Furthermore, since profits should only depend on the experience of *active* firms, $\Pi(\cdot)$ should be indexed by n, not a function of n. In order to be able to adhere to our simpler notation, we assume that $\Pi(n, l_i, l_{-i}) = \Pi(n, l_i, l'_{-i})$ where l_{-i} and l'_{-i} only differ in their last $N-n+1$ components.

constant with respect to l_i, for $l_i > 0$, and $\Pi(n, 0, l_{-i}) = \Pi(n, 1, l_{-i}) - S$, where S is the level of sunk costs.[5]

Assumption 3. *$\Pi(n, l_i, l_{-i})$ is non-increasing in l_{-i}.*

Notice that this assumption does not preclude the possibility of "experience spill-overs." For example, it may be the case that firm i's increased experience results in a reduction of firm j's cost. However, the effect on firm i's cost would have to be stronger than the effect on firm j's cost, such that firm j's equilibrium payoff would actually (weakly) decrease with firm i's increased experience.

Assumption 4. *$\Pi(n, l_i, l_{-i}) \leqslant \Pi(n, l_i + 1, l_{-i} + e_{n-1})$ if $l_i \leqslant l_j$, $\forall j \leqslant n$.*[6]

That is, if all incumbent firms learn one extra step, then the least experienced firm's payoff cannot get worse. Sufficient conditions for this assumption to hold are that (i) the derivative of firm i's profits with respect to its own level of experience is greater than the derivative with respect to firm j's level of experience and (ii) the experience curve is concave; that is, the derivative of firm i's profits with respect to its own level of experience is decreasing.

Assumption 5. *There exists a finite T such that $\Pi(n, l_i, l_{-i})$ is constant in l_k if $l_k \geqslant T$, for any k.*

In other words, experience effects vanish in finite time. This assumption has no particular economic meaning. Its only purpose is to simplify calculations. This would hold, for example, if experience reduces costs, and the latter reach a lower bound after a finite number of periods.

Denote by $\Pi(n, l_i, \infty)$ the limit of $\Pi(n, l_i, l_{-i})$ as $l_{-i} \to \infty$ and by $\Pi(n, \infty, \infty)$ the limit of $\Pi(n, l_i, \infty)$ as $l_i \to \infty$.

Assumption 6. *$\sum_{k=0}^{\infty} \delta^k \Pi(N, k, ke_N) < 0$, $\Pi(1, 0, 0) > 0$, and $\Pi(n, l_i, l_{-i}) \neq 0$, $\forall n, l$.*

The first two conditions imply that the market is too small to accommodate all potential entrants, but sufficiently large for one firm alone to make money. This is assumed for the sole purpose of avoiding trivial solutions. The third condition is a genericity condition.

DEFINITION 1. A Markov Perfect Equilibrium *is a subgame perfect Nash equilibrium with the property that strategies depend only on the state of the game, defined by the vector of experience levels l.*

[5] Notice that implicitly we assume that a firm which exits would not have to pay S upon reentry.

[6] e_{n-1} is a vector with 1's in the first $n-1$ positions and 0's elsewhere.

Since experience advantages vanish in finite time (Assumption 5), we will identify states l and l' which only differ in component i and such that l_i, $l'_i \geq T$.

We can now state our first result, which pertains to existence and uniqueness of equilibrium. In the proof of the following result, we will make use of the additional assumption that the discount factor is not too large. Specifically, given a profit function $\Pi(n, l_i, l_{-i})$, there exists a $\bar{\delta} > 0$ such that the result holds for all $\delta < \bar{\delta}$. (In all applications we have considered, one can actually set $\bar{\delta} = 1$.)

THEOREM 1. *Among the Markov Perfect Equilibria, there exists exactly one with the properties that*

(i) *strategies are symmetric, and*

(ii) *in each period, active firms have the same or longer experience than inactive firms.*

Proof. We prove the theorem by deriving the equilibrium strategy for each firm and showing that it is unique.

(Step 1) Condition (ii) of the theorem implies that for every state l, equilibrium strategies are such that firms with high levels of experience choose "in" with probability one, and firms with low level of experience choose "out" with probability one. This leaves at most a set of firms of equal experience which might select "in" or "out." By Condition (i) of the theorem, each of these firms must select "in" with equal probability.

(Step 2) Condition (ii) and Assumption 3 imply that choosing "out" with probability one during a number of periods and then "in" at some later period is a dominated strategy. By anticipating the time of entry a firm would do (strictly) better, for it would be facing less experienced incumbents and receiving a less discounted profit stream.

(Step 3) Define $E(x) \equiv |\{i: l_i = x\}|$ and $G(x) \equiv |\{i: l_i > x\}|$, i.e., the number of firms with experience level equal and greater than x, respectively. Suppose that $E(l_i) > 1$. A necessary and sufficient condition for firm i's equilibrium strategy at state l to be "in" with probability one is that

$$\sum_{k=0}^{\infty} \delta^k \Pi(n, l_i + k, l_{-i} + k e_{n-1}) \geq 0, \tag{1}$$

where $n = E(l_i) + G(l_i)$. This is necessary because by Conditions (i)–(ii) and the previous step of the proof, the left-hand side of (1) gives the maximum equilibrium payoff achievable from state l assuming no firm with less experience than firm i will ever be active. It is sufficient because if firms with less experience choose "in" in equilibrium, it must be that their expected value is non-negative, and by Assumption 2 and Condition (ii) the same must be true for firm i.[7]

(Step 4) Similarly to Step 3, it is a necessary and sufficient condition for firm i to choose "out" with probability one that

$$\Pi(G(l_i)+1, l_i, l_{-i}) < 0. \tag{2}$$

(Step 5) There exists at most one experience level l_i such that neither (1) nor (2) are true. For suppose there were two values $l_i > l_j$ not satisfying these inequalities. Then, a contradiction would follow. Since $l_i > l_j$, $E(l_i) + G(l_i) \leqslant G(l_j) + 1$. By Assumptions 1, 2, and 3, $\Pi(G(l_j)+1, l_j, l_{-j}) \geqslant 0$ implies that (1) is true.

(Step 6) Suppose there is a set of firms, including firm i, whose experience level satisfies neither (1) nor (2). In equilibrium, these firms choose "in" with probability $p(l)$ such that expected value of choosing "in" is zero[8],

$$\sum_{k=1}^{E(l_i)} B(k-1; E(l_i-1), p(l)) \\ \times [\Pi(G(l_i)+k, l_i, l_{-i}) + \delta V_i(l + e_{G(l_i)+k})] = 0, \tag{3}$$

where $B(k; n, p) \equiv \binom{n}{k} p^k (1-p)^{n-k}$ and $V_i(l)$ is firm i's value function at state l. Given our assumptions, there are only a finite number of relevant values $V_i(l)$, which can then be derived recursively. Furthermore, it follows from Assumption 3 that, if the discount factor is not too large, the left-hand side of (3) is strictly decreasing in k, which implies there exists a unique solution for $p(l)$.

(Step 7) The proof is complete by showing that, in equilibrium, if $E(l_i) = 1$, then firm i stays in or out with probability one. Suppose the opposite were true, i.e., neither (1) nor (2) hold. Since by Assumption 6 $\Pi(G(l_i)+1, l_i, l_{-i}) \neq 0$, we have $\Pi(G(l_i)+1, l_i, l_{-i}) > 0$. But since $E(l_i) + G(l_i) = G(l_i) + 1$, it follows from Assumption 4 that $\sum_{k=0}^{\infty} \delta^k \Pi(n, l_i + k, l_{-i} + k e_{n-1}) > 0$, a contradiction. ▌

As was mentioned in the introduction, Condition (i) means that no exogenous coordination is allowed in the entry process. Condition (ii) excludes other "unreasonable" equilibria, as we will see below.

[7] It might seem that when (1) holds as an equality there could be two different equilibrium strategies. The fact is that since $E(l_i) > 1$, by Assumption 1 and Condition (i), "in" with probability one is the only possible equilibrium strategy.

[8] If the expected value were different from zero, then either $p(l) = 0$ or $p(l) = 1$ would be a best response, which contradicts our equilibrium assumptions.

Even though the proof of Theorem 1 is constructive, it is worth reconsidering the equilibrium strategies which support the proposed equilibrium. Since we are dealing with Markov strategies, we can designate a node in the game tree and the subgame starting at that node by a vector of experience levels l. The proof of the theorem shows that the equilibrium behavior strategy for firm i at node l is to choose "in" if and only if

$$\sum_{k=0}^{\infty} \delta^k \Pi(n, l_i + k, l_{-i} + k e_{n-1}) \geqslant 0, \tag{4}$$

where δ is the discount factor and n is the number of firms with experience level greater or equal to l_i; and to choose "out" if and only if

$$\Pi(n+1, l_i, l_{-i}) < 0, \tag{5}$$

where n is the number of firms with experience level (strictly) greater than l_i.[9] If none of the previous inequalities holds, then firm i chooses "in" with probability $p(l)$, where $p(l)$ is determined recursively in such a way that each firm randomizing its entry decision (i.e., $0 < p(l) < 1$) is indifferent between choosing "in" or "out."

From the above description, we can see that the equilibrium of the dynamic game consists of a generalized "grab the dollar"/"war of attrition" game. In the first period, and in subsequent periods where there is still insufficient entry, the set of the most experienced inactive firms randomize their entry decisions. (If there has been no exit in previous periods, this corresponds to the set of all inactive firms.) When there is excessive entry, the set of the least experienced active firms randomize their exit decisions. As we will see form the following theorems, this process actually converges to a stable market structure.

The fact that equilibrium involves mixed-strategies should come as no surprise, since we are dealing with a symmetric game for which there is no symmetric pure-strategy equilibrium. Harsanyi [11] has shown that one may interpret the equilibrium of this complete information game as the limit of the Bayesian–Nash equilibria of the (incomplete information) "perturbed" game, i.e., the game that obtains from the initial game by adding to each player's payoff some privately known disturbance.[10] This

[9] Notice the analogy between this conditions and Eaton and Ware's [6] sufficient statistic for entry in the context of a sequential entry model.

[10] See [8, 21] for examples. We should note that purification may be impossible in some cases. For example, [14] presents an entry model with private information which still involves a mixed-strategy equilibrium. Sufficient conditions for exact purification are given in [21, 23]. In our example, purification is possible if player i's payoff in period t is given by $\Pi(n, l_i, l_{-i}) + \varepsilon_{it}$, where the values of ε_{it} are privately known to player i, i.i.d. according to the commonly known c.d.f. $F_k(\cdot)$ $(k = l_i)$, on the interval $[a_k, b_k]$ such that $a_k \geqslant b_{k-1}$, $\forall k > 1$.

leads to a more realistic interpretation of the equilibrium of the complete information game. Entry mistakes result not from the fact that firms randomize their decisions but rather that each firm has private information on its own payoff and there is no coordination mechanism to account for these information disparities.

It is worth remarking that both conditions in Theorem 1 are necessary to isolate a unique equilibrium. To see this, consider the simple case in which there are two potential firms and $\Pi(1, l_i, l_{-i}) > 0$, $\Pi(2, l_i, l_{-i}) < 0$ for all l_i, l_{-i}. The unique equilibrium satisfying Conditions (i)–(ii) is the following: both firms randomize their entry decisions until one enters and the other one does not. From then on, the firm which chose "in" continues to choose "in" during the remaining periods, and similarly for the firm that chose "out". However, a different equilibrium, satisfying (ii) but not (i), consists of firm 1 being active and firm 2 inactive in every period. A third different equilibrium, satisfying (i) but not (ii), consists of firms mixing between entering and not entering until one stays in and the other one out; and, from then on, alternating between staying in and out.[11]

In the remainder of this section we focus on the time path of the variable X_t, the equilibrium number of active firms at time t. The core of the paper consists of the following three results.

THEOREM 2. *X_t converges with probability one.*

Proof. Assumption 5 and (1) imply that for a large enough t, if firm i chooses "in" with probability one at time t then it will do the same in subsequent periods along the equilibrium path. A similar argument applies for firms choosing "out" with probability one. Suppose that in state l there are no indifferent firms. Then, the state is "absorbing," in the sense that the set of firms choosing "in" remains the same in all subsequent periods, and thus X_t converges. Alternatively, suppose that in state l there is a set S of

[11] The refinement of subgame perfection is also necessary for uniqueness. To see this, consider a subgame beginning in period $T-1$. There are two potential firms, with experience levels $l_1 > l_2$. Assume that

$$\Pi(2, l_2, l_1) < 0$$
$$\Pi(1, l_1, l_2) < 0$$
$$\Pi(1, l_1, l_2) + \delta\Pi(1, l_1 + 1, l_2) > 0$$
$$\Pi(2, l_1 + 1, l_2) > 0$$

which is consistent with Assumptions 1–6. The equilibrium satisfying the conditions of Theorem 1 calls for firm 1 to be in the market, and firm 2 not to, in both periods. However, there exists another equilibrium in which both firms are inactive in both periods, under the (incredible) threat that firm 2 will enter the market in period T if firm 1 enters the market in period $T-1$.

firms which randomize their entry decisions. Since there are only a finite number of relevant states (by Assumption 5), the equilibrium probability of entry is bounded away from zero and one. Therefore, not only is the set of indifferent firms in the following state enclosed in S but with probability bounded away from zero it is strictly enclosed in S. This implies that the set of indifferent firms converges to the empty set with probability one, which in turn implies the theorem. ▮

An interesting property of the equilibrium path, related to Theorem 2, is that for a large enough t and for a given state l there exists a value n such that $X_t = n$ implies $X_{t'} = n$ for $t' > t$.

THEOREM 3. *X_t converges to n with positive probability if and only if*

$$\sum_{k=0}^{\infty} \delta^k \Pi(n+1, k, \infty) \leqslant 0 \tag{6}$$

$$\Pi(n, \infty, \infty) \geqslant 0. \tag{7}$$

Proof. (Necessity) Suppose that $\Pi(n, \infty, \infty) < 0$ and consider the set of equilibrium paths which converge to a market structure with n active firms. Along an equilibrium path, there exists a T such that for $t > T$ n firms are active and all earn negative profits. But this implies that there are active firms which strictly prefer to stay out, or that there is a set of active firms which are indifferent between staying in and staying out. The first possibility contradicts the assumption of equilibrium, and the second occurs with probability zero, for since $\Pi(n, l_i, l_{-i}) < 0$ the probability that an indifferent firm chooses "out" is bounded away from zero. A similar argument applies to the case when $\sum_{k=0}^{\infty} \delta^k \Pi(n+1, k, \infty) > 0$.

(Sufficiency) By Assumption 6, in state $l = 0$, the equilibrium strategy is to enter with probability p, $0 < p < 1$. Exactly n firms enter with positive probability. By Assumptions 2 and 6, and by (2), in period one it cannot be an equilibrium strategy to exit with probability one. Therefore, exit will occur with probability $q < 1$, and with positive probability (possibly with probability one) no firm will exit. By the same line of reasoning, no firm will exit during T periods with positive probability. ▮

COROLLARY 1. *The limit set of X_t is given by $\{\underline{n}, ..., \bar{n}\}$, where $\underline{n}$ is the minimum n such that* (6) *holds and $\bar{n}$ is the maximum n such that* (7) *holds. This set is non-degenerate if and only if*

$$\sum_{k=0}^{\infty} \delta^k \Pi(\underline{n}, k, \infty) < 0. \tag{8}$$

Proof. Since $\underline{n}$ is a limit point of the equilibrium number of firms, we have from Theorem 3

$$\sum_{k=0}^{\infty} \delta^k \Pi(\underline{n}+1, k, \infty) \leqslant 0 \tag{9}$$

and

$$\Pi(\underline{n}, \infty, \infty) \geqslant 0. \tag{10}$$

If $\underline{n}$ is to be the lowest value in the limit set, it must be the case that $\underline{n}-1$ is not a limit point, i.e.,

$$\sum_{k=0}^{\infty} \delta^k \Pi(\underline{n}, k, \infty) > 0 \tag{11}$$

or

$$\Pi(\underline{n}-1, \infty, \infty) < 0. \tag{12}$$

Since the latter inequality is impossible by (10) and Assumption 1, (11) must be true and the first part of the result follows.

Similarly, since $\bar{n}$ is a limit point of the equilibrium number of firms, we have

$$\sum_{k=0}^{\infty} \delta^k \Pi(\bar{n}+1, k, \infty) \leqslant 0 \tag{13}$$

and

$$\Pi(\bar{n}, \infty, \infty) \geqslant 0. \tag{14}$$

If $\bar{n}$ is to be the highest value in the limit set, it must be the case that $\bar{n}+1$ is not a limit point, i.e.,

$$\sum_{k=0}^{\infty} \delta^k \Pi(\bar{n}+2, k, \infty) > 0 \tag{15}$$

or

$$\Pi(\bar{n}+1, \infty, \infty) < 0. \tag{16}$$

Since the former is impossible by (13) and Assumption 1, the latter must be true and the second part of the result follows. ▌

Notice that the condition for $\underline{n} \neq \bar{n}$ (non-degenerate limit set) implies that experience is a relevant variable.

3. Discussion

The results in the previous section state that X_t converges, with probability one, to a random variable with support $\{\underline{n}, ..., \bar{n}\}$. This random variable is non-degenerate ($\underline{n} \neq \bar{n}$) if (8) holds. The latter implies that experience is a relevant variable, that is, for small values of k, $\Pi(n, k, \infty)$ is "much smaller" than $\Pi(n, \infty, \infty)$.

Notice that the support $\{\underline{n}, ..., \bar{n}\}$ does not depend on the number of potential entrants. However, the distribution of X_t on $\{\underline{n}, ..., \bar{n}\}$ will presumably depend on N.

Conditions (6)–(7) constitute a particular set of no entry–no exit conditions. In the particular case when there are no experience advantages, one gets the usual conditions $\Pi(n+1) \leqslant 0$ and $\Pi(n) \geqslant 0$, which yield a unique value of n (by the third part of Assumption 6). If experience advantages are important, however, then there can be different values of n satisfying the no entry–no exit conditions.

It is useful to compare the results in the previous section with the case of coordinated entry. In the latter, the equilibrium number of firms, $\hat{n}$, is given by

$$\sum_{k=0}^{\infty} \delta^k \Pi(\hat{n}, k, ke_{\hat{n}}) \geqslant 0 \geqslant \sum_{k=0}^{\infty} \Pi(\hat{n}+1, k, ke_{\hat{n}+1}), \tag{17}$$

which, by Assumptions 4 and 6, yields a unique solution. One can easily see that the first inequality, together with Assumption 4, implies (7), whereas the second inequality, together with Assumption 3, implies (6). Thence we conclude that $\underline{n} \leqslant \hat{n} \leqslant \bar{n}$.

As an example, consider the case of entry with sunk costs, which was alluded to in the previous section: $\Pi(n, l_i, l_{-i}) = \Pi(n)$, $l_i > 0$, $\Pi(n, 0, l_{-i}) = \Pi(n) - S$. In this case, one can easily check that $\hat{n} = \underline{n}$ and, if $S > \Pi(n)$, $\hat{n} < \bar{n}$: the long-run number of firms will be (weakly) greater under uncoordinated entry than under coordinated entry.

4. Related Literature

It has been known for some time that increasing returns allow the existence of multiple equilibria. In the industrial organization literature, this can be found in the work of Helpman and Krugman [12], dealing with dynamic scale economies, and Katz and Shapiro [17], dealing with network externalities. Both these papers considered essentially static games as a proxy for a more complex dynamic framework. The approach taken in this paper is slightly different. In fact, by imposing a number of reasonable properties, we are able to restrict to a single equilibrium of an explicit dynamic game. However, since firms randomize their decisions and there are experience advantages, this equilibrium may lead to different possible outcomes. One can of course interpret the limit points of X_t as equilibria, in the sense that they correspond to stable market structures. In that sense, our model provides an explicit process for equilibrium selection in the corresponding static game.

There is a literature on stochastic models of entry and exit, which includes the work of Jovanovic [15], Hopenhayn [13], and Lambson [18]. The present model relates to this literature in that the equilibrium market structure emerges as the outcome of a dynamic process involving both entry and exit. There are, however, important differences. The above models consider competitive industries with firms of infinitesimal size. The coordination problem is absent and market structure is an ergodic process. In our model, X_t is a path-dependent variable because there are experience advantages *and* firms are non-atomic.

Jovanovic [16] presents an example where entry is a path-dependent process. His model differs from ours in that he considers the case of sequential entry. Moreover, instead of experience advantages in the sense considered in this paper, he examines the case when there is incomplete information about some common value. In equilibrium, the success of the first entrants influences the remaining firms' posterior about the expected payoff from entry, and thus history matters.

5. Conclusion

In this paper, we have considered a dynamic model of uncoordinated entry with experience advantages. Entry mistakes (excessive or insufficient entry) influence the long-run market structure, which is a random variable. Our results provide the exact bounds for this random variable.

Unfortunately, there has been little empirical work on entry into new markets which might provide evidence on the model presented here. Based on an empirical investigation of the diffusion of product innovations, Gort an Klepper conclude that "there is no unique equilibrium of firms in a market as is suggested in some theories of entry. The ultimate number of producers ... and the number at each preceding point in time depends upon the sequence of events to that point" [10, p. 634]. This seems to provide evidence of the path-dependent nature of entry dynamics. However, their conclusion is only valid under the assumption that the various industries considered have similar payoff structures. A more appropriate experiment for our model would be to compare the evolution of industries with geographically limited markets across different geographic areas.

Alternatively, one could group Gort and Klepper's industries according to importance of experience advantages. A testable implication of our model is that X_t should have a greater "permanent component" in industries where experience advantages are important.

The work of Dunne *et al.* [5] presents some evidence which seems consistent with our model (although it is consistent with other models as well). In particular, the data shows that "periods of higher than average entry rates for an industry are also periods of lower than average exit rates. The correlation between the entry rate in period t and the exit rate in period $t+1$ is positive, which indicates that higher than average entry rates in one period are followed by higher than average exit rates in the next period" [5, p. 508]. Furthermore, the rate of exit is highest amongst the most recent entrants (cf. Table 8).

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