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DOES HISTORY MATTER ONLY WHEN IT MATTERS LITTLE? THE CASE OF CITY-INDUSTRY LOCATION

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ABSTRACT

When will an industry subject to agglomeration economies move from an old, high-cost site to a new, low-cost site? It is argued that history, in the form of sunk costs resulting from the operation of many firms at a site, creates a first-mover disadvantage that can prevent relocation. It is demonstrated that developers of industrial parks can partly overcome this inertia through discriminatory pricing of land over time, and empirical evidence is provided that they actually engage in such behavior. It is also shown that other aspects of developer land-sale strategy can be a source of information on the nature of interfirm externalities.

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I. Introduction

The tendency of different firms within an industry to cluster together has been noted at least since Marshall [1961 (1890)], for whom this tendency was a powerful testament to the existence of economies of agglomeration. Because these agglomerated industries sometimes form the nuclei of cities it is convenient to refer to them as "city-industries".[1] Contemporary economists interested in understanding the economics of city-industries have brought them under the heading of economic behavior that displays strategic complementarities: an agent is better off when other agents choose the same action that he does, rather than being worse off due to increased competition. Models of this type of behavior, admirably surveyed by Krugman [1991a], typically display multiple equilibria. This property is alleged in the recent work of Arthur [1990] and Krugman [1991b] to extend to city-industries, where the equilibria are locations in different regions of the same country or in different countries entirely. This same work attempts to demonstrate that "history" plays a large role in determining which equilibrium is actually chosen as the outcome.

In Arthur's model, firms enter the industry in sequence. Each firm chooses a location on the basis of how many firms are there at the time of entry and a random vector that gives the firm's tastes for each possible location. If agglomeration economies are unbounded as the number of firms increases, then as the industry grows large one location takes all but a finite set of firms with probability one. Which location is chosen depends on the locational preferences of the early entrants and thus on historical accident. In Krugman's model, history determines an initial distribution of workers between two locations, which in turn determines the initial difference in wage rates between these two locations. Although Krugman's workers are endowed with perfect foresight unlike Arthur's purely myopic firms, given his assumption of a cost of changing locations that is convex in

[1]I have borrowed this term from Glaeser et al. [1992].

the aggregate rate of movement, his workers all wind up (for certain ranges of parameter values) in the location with the higher initial wage, just as though they were responding to the current wage only.

The importance of the result that "history matters" in choosing which equilibrium is the outcome is that there is no assurance that history will choose the most efficient outcome. A region that "should" have a comparative advantage in the city-industry because the opportunity cost of its labor is low or its resource endowments are well suited for the industry's production may be denied the industry by historical accident. By taking this logic perhaps farther than its authors intended it to go, we could conclude that certain regions or countries may be condemned to agricultural poverty, not because of lack of human and physical resources or because of poor governmental management, but simply because of bad luck.

On the other hand, much of world economic history since World War Two concerns the shift of agglomerated industries from high-cost to low-cost locations, suggesting that in the city-industry case inefficient "equilibria" may not deserve the name. In response to lower wages and the invention of air-conditioning, the United States has witnessed a massive shift of its manufacturing industry from the old cities of the Northeast and Midwest to the so-called Sunbelt, swelling medium-sized Southern and Western cities based on distribution and service into major manufacturing metropolises. In many branches of manufacturing the dominant location of supply to the world market has changed more than once. For example, during the 1980s Taiwan replaced Europe and Japan as the world's major exporter of bicycles, and in the early 1990s China has emerged as the second leading exporter and may conceivably displace Taiwan by the end of the decade [Mody et al., 1991]. Bateman and Mody [1991] document the rise of a "bicycle city" in the Special Economic Zone of Shenzhen. They also describe the formation of other agglomerated export-oriented industries in the coastal provinces of Fujian and Guangdong, including shoes and garments. The key common element in these examples of shifts of agglomerated industries around the globe and the shift of agglomerated industries within the United States is the attraction of lower costs, especially lower labor costs, rather than the attraction of new markets: manufacturing industry in the United States did not move to the Sunbelt primarily to serve the Sunbelt market. The attraction of low wages for the formation of new city-industries is demonstrated more generally by the econometric study of Glaeser et al. [1992], who find that employment growth between 1956 and 1987 in city-industries other than the four that were the largest in the city in 1956 depends negatively on the city's 1956 wage outside those four industries.

The questionable sustainability of inefficient city-industry locational equilibria will come as no surprise to an urban economist familiar with the "system of cities" model of Henderson [1985]. Henderson argues that the existence of a more efficient site at which the city-industry can locate creates a profit opportunity for entrepreneurs whom he calls "developers". A developer can finance purchase of the land at the more efficient site by selling shares in a "land bank company" to agents who move there, pay these agents a level of dividends competitive with that of the communities from which they move, and still retain a profit. It is implicitly assumed that by guaranteeing a competitive level of dividends the developer can avoid a coordination failure that would leave every agent at the inefficient site with the expectation that if he were to move, no one else would follow and his share in the land bank company would be worthless.[2] The Henderson argument effectively denies any role to history in determining city-industry location except when the locations are economically identical. Thus history matters for the choice of city-industry location only when it does not "matter" at all.

Henderson's model of developer behavior is highly stylized. I contend that a great

[2]As Dybvig and Spatt [1983] point out in a more general framework, *government* guarantees would solve this problem. Indeed, public-private partnerships are common in the area of industrial park development discussed below. In this paper, however, I focus on private developers because they operate on a strictly for-profit basis, the only ambiguous case being Tampa Industrial Park (cited in Section III below) which was developed by the Committee of 100 of the Greater Tampa Chamber of Commerce.

deal about the economics of agglomeration and the degree of importance of history in determining the location of city-industries can be learned by looking at the behavior of real-world developers, and in particular at the behavior of developers of "industrial parks" (also called industrial estates or industrial districts) who are explicitly attempting to capitalize on firm complementarities. The scale of these parks can be sufficient to support a medium-sized city. For example, about 25,000 workers are employed at Irvine Spectrum, an industrial park in Orange County, California, which is itself a successor to the Irvine Business Complex previously developed by the Irvine Company where about 105,000 workers are employed. An extended quotation from a recent article on the city of Irvine [Siegle, 1992] illustrates the power of an industrial park to facilitate agglomeration:

> The massive, 2,600-acre master-planned business center was built with the goal of creating a center that would attract companies interested in high-tech and international trade. The plan worked. With approximately 1,000 tenants, Irvine Spectrum houses 177 high-tech and biomedical firms, 25 Fortune 500 companies and serves as the American regional headquarters of 21 Pacific Rim companies. Robert Hovee, president of Life Support Products and an Irvine Spectrum tenant, believes that the building of such an infrastructure created a kind of "self-fulfilling prophecy" and is one of the factors explaining why Irvine has emerged as an axis for international and high-tech businesses. "This area is now the center for biomedical engineering in the United States," Hovee notes. "And as a result, people doing business in the medical arena are going to have to come here sooner or later." (p. 14)

The plan of the remainder of this paper is as follows. In Section II a model of how the weight of history might sustain an inefficient equilibrium is formulated and the essence of developer strategy to overcome history is shown to be discriminatory pricing of land over time. The next section presents empirical evidence concerning the validity of this model. Section IV addresses more subtle elements of developer land-sale strategy and shows that they can shed some light on the nature of interfirm externalities, and Section V concludes.

II. Reexamining the Role of History in City-industry Location

It is useful to begin with a model that I believe distills the essential elements from the papers cited above on multiple equilibria for city-industry location and the role of history in determining the choice of equilibrium, and from earlier work on the same topics in the literature on interregional and international trade [e.g., Helpman and Krugman, 1985, Chapter 4]. The assumptions of the model are as follows:

Assumption 1. There exist two regions, which may or may not be part of the same country.

Following the trade literature I call these the "home" and "foreign" regions, marking variables associated with the latter by an asterisk. Each region contains one potential site for the city-industry, the location of which could be determined by the existence of particularly favorable transportation possibilities.

Assumption 2. There exist N (an integer) identical "footloose" firms in the city-industry.

In light of the discussion of industrial parks above it is important that I model firms as the decision-makers regarding location.

Assumption 3. Each firm earns profit $\pi(n)$ in the home region and $\pi^*(n^*)$ in the foreign region, where π and π^* are monotonically increasing and $n + n^* = N$.

Here I am following Arthur [1990] in specifying economies of agglomeration as a function of the number of firms in the region. We could think of these profit functions as generated by identical, price-taking entrepreneurs who maximize the rents (profits) to the time they supply inelastically to a production process that displays constant returns to scale at the firm level.

Assumption 4. $\pi^*(x) > \pi(x)$ for $0 \leq x \leq N$.

This reflects lower costs in the foreign region. These lower costs might be due to lower wages, which in turn could be caused by lower foreign productivity in nonfootloose industry such as agriculture.

Assumption 5. There exists $\bar{n}^* > 1$, not necessarily an integer, such that $\pi(N - \bar{n}^*) = \pi^*(\bar{n}^*)$.

If this assumption did not hold every firm would trivially choose to locate in the foreign region.

We can model the N firms as playing a game in which there are two pure strategies, locate at the home site and locate at the foreign site. It is clear that there exist only two Nash equilibria in pure strategies: all firms locate at the home site and all firms locate at the foreign site.[3] It follows from Assumption 4 that the latter equilibrium is more efficient. The preferred method of choice between these equilibria in the trade literature [see, e.g., Panagariya, 1986] is the Marshallian adjustment process, which works as follows. History gives us an initial distribution of firms $N-n_0^*$, n_0^* between the home and foreign sites. Firms then move towards the site that offers the higher profit, i.e., towards the home site if $n_0^* < \bar{n}^*$ and towards the foreign site if $n_0^* > \bar{n}^*$. The process is self-reinforcing, and thus history (n_0^*) uniquely determines which equilibrium obtains provided that $n_0^* \neq \bar{n}^*$. Intuitively, behind the Marshallian adjustment process is an adaptive expectations story in which each firm's expectations concerning what strategy other firms will play are based on what strategies they have played in the past. If other firms are expected to play the same strategy in the future as they did in the past then it makes sense for any firm taking other firms' strategies as given to follow the Marshallian

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[3]Suppose there existed a pure strategy Nash equilibrium where $\bar{n}^*$ firms play locate at the foreign site and $N - \bar{n}^*$ firms play locate at the home site. Equilibrium requires that $\pi^*(\bar{n}^*) \geq \pi(N-\bar{n}^*+1)$ *and* $\pi(N-\bar{n}^*) \geq \pi^*(\bar{n}^*+1)$. These requirements contradict the assumption that $\pi^*(x)$ is monotonically increasing. There does exist, however, a symmetric mixed strategy equilibrium. In such an equilibrium firms must be even worse off (on an ex ante basis) than they are in the pure strategy equilibrium where they all locate at the home site. The reason is that each firm must be indifferent between playing the mixed strategy and choosing the home site with probability one, yet the expected payoff from the latter strategy is strictly lower than it would be if all firms chose the home site with probability one.

adjustment rule.[4]

In this paper it is my contention that history *does* influence which city-industry locational equilibrium obtains, but that at least in the post-World War Two period the channel for that influence is usually *not* the one in the Marshallian analysis (or in the related analyses cited in Section I). In the Marshallian analysis history is assumed to give us an initial distribution of firms between two competing sites. In post-World War Two reality, however, the situation is typically that all firms are located at an old, established site, and some change occurs that makes a new, lower wage site much more attractive than it was when the old site was established--perhaps a technological change such as invention of air-conditioning or a political change such as a policy of welcoming rather than discouraging foreign investment or establishment of a free-trade zone. The advantage conferred on the old site by history is then not that it influences expectations about what firms will do, because the information communicated by these past choices is now irrelevant. Rather, the old site has an advantage over the new one because the operation of many firms there inevitably results in some sunk cost that would have to be incurred anew should firms move to a different site. Because the benefits of these sunk costs do not completely vanish when firms relocate, the productivity of a site may be as strongly influenced by the number of firms that have ever been there as by the number of firms that are there now.

For the remainder of this paper I will take this position, and thus the influence of history, to an extreme and assume that the productivity of a site depends *only* on the number of firms that have been there in the past. A plausible story for why this might be

[4]The Marshallian adjustment process would not pass muster as an "equilibrium refinement" in game theorists' parlance. Nevertheless, as can be seen from Crawford [1991, section 3], in the two-strategy case the Marshallian dynamics lead to the same outcomes as the "evolutionary" dynamics that are gaining popularity among game theorists as an equilibrium selection mechanism. Crawford offers an adaptive interpretation of evolutionary dynamics similar to the adaptive expectations rationale for the Marshallian dynamics that I give here.

the case builds upon one of the standard reasons given for agglomeration economies: firms are able to observe and learn from what other firms do without paying in full for the benefit of this information.[5] In particular I suppose that the information that spills over is generated by learning-by-doing about how to operate most efficiently at a given site: how best to adapt to the climate, labor force, transportation opportunities, local government regulations, and so on.[6] If each entrepreneur-firm reveals one idea as a result of starting up production, then the profit functions π and π^* will depend on the total number of firms that were present at the site by the end of the preceding period or the largest number that has ever been there, whichever is greater. This formulation implicitly assumes that knowledge about how to operate most efficiently at a given site does not depreciate. Formally, we can replace Assumption 3 above with

Assumption 3′. Each firm earns profit $\pi[\max_{-\infty < \tau \leq t-1} (n_\tau)]$ in the home region and $\pi^*[\max_{-\infty < \tau \leq t-1} (n^*_\tau)]$ in the foreign region, where t denotes the current period.

There are two practical consequences of this "as if" model of externalities. First, productivity at the old site does not decline if firms leave it. Second, productivity at the new site will depend on the number of firms lagged one period. As we shall see, this model will help us understand both the difficulties history creates for relocation of city-industries and the behavior of developers attempting to overcome those difficulties.

Let us now reexamine the game being played by our N entrepreneur-firms. I relabel the home and foreign sites the "old" and "new" sites, respectively, and label location at the old site "staying" and location at the new site "moving". These new labels reflect the

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[5]Bateman and Mody [1991] term this process, which they observed in the Special Economic Zones in Fujian and Guangdong provinces in China, "watching and talking". Evidence of total factor productivity benefits from the average level of education in U. S. cities, and thus implicitly for the importance of information spillovers, is given in Rauch [1993a]. More direct evidence for the localization of knowledge spillovers within cities is provided by patent citations, according to Jaffe, Trajtenberg, and Henderson [1993].

[6]This is similar to Bardhan's [1971] model of spillovers within an infant industry that is trying to adapt best-practice foreign technology to local conditions.

assumption, based on the previous discussion, that all firms are initially located at the old site. Suppose all firms were to decide to move. In the first period, each firm would lose $\pi^*(0) - \pi(N)$ as a result of moving, since by assumption zero firms have ever been at the new site and N firms have ever been at the old site before the first period. In all subsequent periods each firm would gain $\pi^*(N) - \pi(N)$. Assume that the discounted sum of gains outweighs the loss. Given this behavior on the part of all other firms, any individual firm has the option to stay the first period and avoid the loss $\pi^*(0) - \pi(N)$, receive the gain $\pi^*(N-1) - \pi(N)$ in the second period, and receive the gain $\pi^*(N) - \pi(N)$ in all subsequent periods. I call this behavior "wait and see", since the firm waits and sees what all the other firms have learned, and then moves. If the firm's own contribution to learning is small relative to the total contribution of all firms, wait and see does better than moving. But then no firm will move!

After adding one assumption we can formalize the preceding discussion in a Proposition:

Assumption 6. There exists a positive world interest rate of i per period and an infinite time horizon.

Proposition 1. No firm moves in any *symmetric* pure strategy Nash equilibrium if

(i) $[\pi^*(0) - \pi(N)]/(1+i) + [\pi^*(1) - \pi(N)]/i(1+i) \leq 0$, and

(ii) $[\pi^*(0) - \pi(N)]/(1+i) + [\pi^*(N) - \pi^*(N-1)]/(1+i)^2 \leq 0$.

In stating conditions (i) and (ii) I establish the convention of discounting all payoffs back to period zero that I will maintain for the remainder of this paper. Condition (i) insures that it does not pay for a firm to move (locate at the new site) if no other firm does. Condition (ii) insures that wait and see does better than moving when firms play symmetric pure strategies.

Under conditions (i) and (ii) every firm prefers to let all other firms move from the old to the new site first. However, it seems possible that if we introduce some asymmetry among firms in their desire and ability to move, it might be possible for one or more first movers to arise that other firms could follow in some equilibrium order. An extreme form of such asymmetry is in Farrell and Saloner [1985, section 2]:

Assumption 7. Firm j has the opportunity to move only in period j.

This fixed sequence of moving opportunities is artificial, yet it is implicit in many models in which agents "arrive" at a decision node in some fixed sequence [e.g., Arthur, 1990, Bikhchandani, Hirshleifer, and Welch, 1992]. In the present context a fixed sequence of moving opportunities could arise, for example, because firms' plants are subject to "one-hoss shay" style depreciation, i.e., 100 percent depreciation in one period, with exactly one firm having its plant wiped out in each period.

Suppose that all firms were to move in the fixed order specified by Assumption 7. We can write the payoff to firm j discounted back to time zero as

(1) $$P_j = \Sigma_{t=j}^{N}[\pi^*(t-1) - \pi(N)]/(1+i)^t + [\pi^*(N) - \pi(N)]/i(1+i)^N.$$

It is useful to define $\hat{n}^*$ by $\pi^*(\hat{n}^*) = \pi(N)$ so that $\pi^*(t-1) - \pi(N) > 0$ for $t > \hat{n}^*+1$. We can now prove a modification of the corollary to Proposition 1 in Farrell and Saloner [1985, p. 73]:

Proposition 2. If $P_1 > 0$, then the unique subgame perfect equilibrium is for all firms to move.

Proof of Proposition 2. First note that if P_1 is positive then $P_2,\ldots,P_N$ are all positive because as the index j increases only nonpositive terms are deleted from P_j until $j > \hat{n}^*+1$, at which point P_j becomes a sum of positive terms only. It follows that $P_1 > 0$ ensures that, for each firm j, if firms 1 through j-1 have already moved it will also choose move over stay, provided it believes all the remaining firms will follow. Since firm j knows this is true for firms j+1 through N it knows they will move if it does; so it moves.

Note the implicit increase in information requirement involved in this proof: it is assumed that each firm has some knowledge of the payoffs of all other firms (or at least all others that follow it). The stronger assumption that firms' payoffs are common knowledge will be maintained throughout the rest of the paper.

We see that once the first firm moves, all other firms "jump on the bandwagon" and the city-industry relocates to the new site. However, we can also prove:

Proposition 3. If $P_1 < 0$, then the unique subgame perfect equilibrium is for all firms to stay.

Proof of Proposition 3. If $P_1 < 0$, then firm 1 chooses stay over move. But then the payoff to firm 2 from moving if all subsequent firms move, discounted back to period 1, is strictly smaller than P_1, so firm 2 also chooses stay over move, and so on. Thus if firm 1 does not start the bandwagon rolling, neither will any subsequent firm.

From these two Propositions it follows that to evaluate the conditions under which the city-industry will relocate from the high-wage to the low-wage site we need only evaluate the conditions under which $P_1 > 0$. P_1 is more likely to be positive:

(a) the greater is $\pi^*(x)$ relative to $\pi(x)$;

(b) the lower is the interest rate, since this increases the later, positive terms relative to the early, negative terms;

(c) the less there is to learn (the less important is agglomeration), i.e., the greater is $\pi^*(0)$ relative to $\pi^*(N)$;

(d) the "faster" is learning (the greater the share of learning done by the first firms), where π^{*1} displays faster learning than π^{*2} if $[\pi^{*1}(j) - \pi^{*1}(0)]/[\pi^{*1}(N) - \pi^{*1}(0)] \geq [\pi^{*2}(j) - \pi^{*2}(0)]/[\pi^{*2}(N) - \pi^{*2}(0)]$ $\forall$ j = 1,...,N-1, with at least one strict inequality. An increase in the number of firms N, keeping the amount there is to learn constant, can be treated as equivalent to slower learning.

Note that as the interest rate goes to zero *any* advantage of the new site over the old ($\pi^*(N) > \pi(N)$) is sufficient to cause the city-industry to relocate and we have the Henderson model where history does not matter.

Proposition 3 shows that the city-industry will not relocate to the more efficient site spontaneously if the first firm with an opportunity to move does not find it profitable to do so. By the same token, if only the first firm (or first few firms) does not find it profitable to move if all other firms follow, a large profit could be made if one could induce this firm to move and then capture the payoffs of the following firms. I now argue that it is natural for the institution of the industrial park to develop in order to serve as a vehicle for realizing this profit opportunity. This argument requires me to add a potential role for land to my model. I therefore add the following three assumptions:

Assumption 8. Each firm inelastically demands land on which to build its plant, the cost of which must be subtracted from its profits. Without loss of generality I set the amount of land demanded by each firm equal to one unit.

Assumption 9. Each site contains more than N units of land suitable for use by the city-industry.

Assumption 10. Land is supplied competitively.

Since it follows from Assumptions 8-10 that the price of land is zero, in themselves these assumptions do not affect the validity of either Propositions 1-3 or the preceding Marshallian analysis of choice of equilibrium.

Suppose that an entrepreneur, whom I will call a developer, could acquire all of the land suitable for use by the industry in question at the new site. His optimal plan is then to practice perfect price discrimination over time,[7] i.e., he should establish a schedule of land prices equal (in present discounted value) to the schedule of payoffs P_j.[8] How can the

[7]Katz and Shapiro [1986, section IV.B.] study the optimal pricing plan for the monopoly supplier of a new technology subject to network externalities that is competing with an old technology priced at marginal cost. The externalities are a function of the contemporaneous number of agents that purchase the new technology. There are two periods in each of which a generation of consumers decides which technology to buy. The optimal plan can involve pricing below marginal cost to the first generation of consumers, just as the developer may want to subsidize the first firm in the present model.

[8]Could firms undercut this price schedule through resale? It is easily shown that any firm will be indifferent at any point in time between reselling its land and returning to the old site and continuing operations at the new site. This indifference is eliminated in favor of staying at the new site if the seller extracts anything less than the full payoff to moving from the buyer. In any case, the developer can always prevent resale by signing long-term leases with the firms instead of giving them title to the land. Lee and Wong [1958, p. 24] state, "Some developers write restrictions into the lease or sales agreement and require occupants to build on purchased or leased property within a given period of time (usually one year). If the time limit is not observed, the developer customarily has the option of

developer obtain this local land monopoly? One method is for the developer to buy all the land suitable for use by the industry, but this will drive its price above zero and perhaps eat up all of his potential profits. A preferred method is for the developer to buy N units of land at price zero, and then negotiate with local government to zone only his land for use by the industry in question. If bargaining is efficient, the local government will agree to this zoning policy because it maximizes the surplus that it can divide with the developer. Since the local government cannot extract more than the total surplus from the developer, the details of this bargain need not concern us here because they do not affect the developer's profit-maximizing pricing schedule nor what is called below the "viability" of the industrial park. In practice this bargain mainly concerns the level of public amenities provided by the developer and his share of the cost of providing infrastructural services.[9]

The result of this process is an industrial park or district consisting of N units of land.[10] The total profit realized by the developer of the industrial park from his perfect price discrimination strategy is

(2) $$\Sigma_{j=1}^{N} P_j = \Sigma_{t=1}^{N} t[\pi^*(t-1) - \pi(N)]/(1+i)^t + N[\pi^*(N) - \pi(N)]/i(1+i)^N.$$

We can now state the following Proposition:

buying back the property at the original price."

[9]The Urban Land Institute [1988, p. 18] states that, "special zoning districts, established for a single business park or for a combination of developments, have become increasingly common. In return for the right to develop certain amounts of different land uses, a developer agrees to provide designated public improvements and adhere to specific standards of development that are designed to be in the public interest." Efficiency of bargaining can be facilitated by "capture" of the local government by the developer, which is especially likely when the developer has a hand in establishing the local government. This was the case with the Irvine industrial parks mentioned in Section I, with the Boca Raton industrial park cited in Section III below and with the 10,500 acre Bayport petrochemical park in Clear Lake, Texas [described in ULI, 1975].

[10]According to ULI [1988, pp. 13-17], the first planned industrial estate was begun in 1896 in Manchester, England, when a private company purchased a 1,200-acre country estate on the Manchester Ship Channel adjoining the docks. In the United States, the railroads were the most important developers of industrial districts in the pre-World War Two era, beginning with the Original East District in Chicago in 1902 and continuing through the landmark Central Manufacturing District begun in Los Angeles in 1922.

Proposition 4. If expression (2) is positive, a developer practicing perfect land price discrimination over time can successfully engineer the relocation of the city-industry from the old to the new site. We then say that the industrial park is "viable".

Clearly this condition for viability is much weaker than the condition $P_1 > 0$ that obtained in the absence of a developer, although the same four factors that make satisfaction of the latter condition more likely also make satisfaction of the former condition more likely. In terms of the question with which this paper began, the developer reduces the extent to which history can outweigh efficiency in determining city-industry location, although unlike in the Henderson model history can still matter if $\pi^*(N) - \pi(N) > 0$.

Remarks on monopoly power. In a more general model there could be more than one new site capable of competing with the old site for the city-industry. The developer of the most attractive new site would have to lower his schedule of land prices sufficiently to prevent entry by the second most attractive new site. This competition will lower his total profit but, like the bargain with the local government, it cannot affect the viability of the industrial park. More worrisome for the utility of Proposition 4 is the fact that, if we consider a U. S. metropolitan area to be a "site", it is now common to observe more than one large-scale industrial park with vacant land for sale at a given site in the United States. This is not surprising in light of the existence of many jurisdictions within a given metropolitan area, each with its own zoning powers. Often the parks are targeted at different industries and so are not in competition with each other. Direct competition typically results from sequential entry in response to greater than expected demand, a situation beyond the scope of this paper. How much this situation, in contrast with the ideal represented by the Irvine Company's Orange County operations cited in Section I, affects the ability of the developers to price discriminate depends on many factors, including the extent to which the externalities generated by an industrial park travel "across town", the degree to which the developers can differentiate their products through their offerings of services and amenities, and the nature of their oligopolistic interaction. Whether the simple model of price discrimination presented here captures the important features of the data is the subject of the next section.

III. Empirical Evidence

An extensive search of the literature reveals that industrial parks have received no attention from academic economists, but have been studied by economists outside of academia and by the development industry itself. The economists' studies are concentrated in the 1950s, evidently in response to the post-World War Two boom in industrial park development in the United States. This boom is of some interest in itself. Lee and Wong [1958] note that only 4.2 percent of "organized industrial districts" existing in the United States in 1957 were established before 1940. While accelerated diffusion of this institutional innovation might have been expected in any case given post-World War Two prosperity, the analysis of this paper suggests that the reduction in transport costs (especially due to construction of the interstate highway system) was also an important factor because it freed manufacturers from the need to locate next to their major markets and thus created greater possibilities for developers to attract them to new locations. Some further evidence on this point is provided below.

I found four sources that contained price data and/or analysis of pricing strategy for industrial parks: the aforementioned study of Lee and Wong [1958, sponsored by the Stanford Research Institute], two studies by the Urban Land Institute [Boley, 1962 and ULI, 1988, the latter an update of a 1975 study], and a trade journal article by Carestio [1971]. I first address the claim made in Section II that developers get involved in attracting an industry to a new location because the first firm (or few firms) to move loses money by doing so and thus requires a subsidy that the developer can provide. In the 1988 Urban Land Institute (ULI) monograph, entitled *Business and Industrial Park Development Handbook*, a team of writers that included several developers summarized the findings from their survey of experience of leading industrial developers in the United States and their professional associates, from case studies, and from a review of the trade journal literature. Of particular interest for this paper is their description (pp. 168-169) of the typical land-sale strategy for the developer of a "large-scale, long-term business park". In the first stage of development land is sold to one or more "seed tenants" who will "set the reputation and character of the project and of the tenant mix." According to the principal author of the study [Beyard, 1992], these seed tenants are "loss leaders", and if the same terms were offered to all subsequent tenants the developer would "go bankrupt". Quantitative evidence is provided by Lee and Wong (pp. 10 and 16), who find for the developers they surveyed that the cost of acquisition and improvement of land averaged 22.6 cents per square foot and that the initial sales price of lots averaged 18.6 cents per square foot.[11]

The predictions of the model of Section II concerning the time path of land prices in industrial parks cannot be matched as precisely to the available information. Observed prices are current values, rather than values discounted back to the period before the industrial park was established, and reflect factors such as inflation and economic growth that are not present in the model. Nevertheless, the available information is very suggestive and worth reporting:

(a) Like Lee and Wong, Carestio [1971] performed an independent survey of industrial parks, which he used as the basis for a purely cross-sectional regression analysis of the determinants of land price per square foot. He found that the effect of the age of the industrial park was positive and significant.[12] Carestio hypothesizes (p. 18) that, "As time passes, additional portions of the park are absorbed [occupied] so that economies of

[11]Acquisition and improvement averaged only 59.3 percent of total costs. It will be shown in Section IV below that promotion costs can help explain another aspect of developer land-sale strategy.

[12]Note that a naive "vintage" approach would suggest the opposite relationship. Carestio presumably does not use actual occupancy as his independent variable in order to avoid simultaneity bias.

agglomeration are reflected in increased value." He also found a negative and significant effect of distance to the nearest limited access highway interchange and no effect of distance to the central business district of the metropolitan area, providing more evidence consistent with the view that firms move to industrial parks to find an attractive location from which to "export" their output rather than to find a location close to an attractive market.

(b) Lee and Wong do not report actual time paths of prices, but do make two summary statements:

> Land prices in industrial districts increase sharply after the first year to perhaps double the original price. (p. 1)
>
> Analysis of changing land values indicates a pattern of low original prices followed by a sharp increase during the first year or two. Thereafter, prices increase but at a slower rate say many developers. (p. 17)

This pattern of price increases suggests the intuitively plausible interpretation that the economies of agglomeration realized within the park are concave in the number of firms, although it can be shown that concavity of $\pi^*(x)$ is not necessary for the percentage increase in the prices defined by equation (1) in Section II to decrease as the number of firms increases.

(c) Boley [1962] and ULI [1988] each contain two case studies of large-scale industrial parks in which land sale price is reported for more than one time period. Boley [1962, pp. 77 and 91] reports for Brook Hollow Industrial District in Dallas, begun in 1954, that the first two sites sold for $0.10 per square foot and that lots were selling for $1.00 per square foot at the time of writing (1962); and for Tampa Industrial Park, begun in 1956, that the initial land parcel sold for $1,000 per acre, the next two parcels for $2,000 per acre, and that recent sales were in the $5,000-$10,000 per acre range. ULI [1988, pp. 175 and 252] reports for Arvida Park of Commerce in Boca Raton, Florida, that the sales price per acre increased from its initial value of $40,000 in the "late 1970s" to $350,000 at the time of writing (1987); and for Park 10 in Houston, Texas that prices rose from $0.75 per square foot in 1974 to a range of $9 to $18 per square foot in 1987.[13] The most straightforward interpretation of the spectacular land price increases in these case studies appears to be the one suggested by the model of Section II: later tenants are paying for the privilege of benefitting from economies of agglomeration as firms accumulate within the park, allowing the developers to recoup the costs they incurred in subsidizing early tenants.

Alternative explanations. There exist alternatives to the view presented in this paper that developers internalize agglomeration economies within industrial parks. One alternative is that developers simply bet on exogenous increases in the popularity of the areas in which they invest as sites for industrial location. If this view is correct the increases in land prices within industrial parks described above merely reflect increases in the price of land in the surrounding areas (though even then it is conceivable that the causality runs in the reverse direction), possibly combined with elimination of the subsidies provided to the seed tenant(s). It is possible to check this alternative explanation directly for the four case studies given by Boley [1962] and ULI [1988] above. Table I compares the increase in the value of land in these four industrial parks to the increase in the average value per acre of agricultural land and buildings in the counties in which they are located.[14] Suppose we infer from the information supplied by Lee and Wong that the first doubling of land prices within the industrial parks is due to the elimination of the subsidy provided to the first tenants. Even in this case, the maximum proportion of the remaining price increases that can be accounted for by increases in the value of the surrounding land is 48

[13]Houston has no zoning code, but the developer of Park 10 was nevertheless able to obtain monopoly power by purchasing a strip of land along Interstate 10 that was bounded on the north and south by large, unbuildable flood control areas (later turned into Cullen Park) and on the east by existing development, leaving cheap farmland to the west that was developed for moderately priced employee housing.

[14]Values for the years 1956 and 1962 were interpolated using average annual growth rates between 1954 and 1959 and between 1959 and 1964, respectively. Since buildings should only account for a small fraction of the value per acre the increase in this value should be a good measure of the increase in land prices in the surrounding area. The Brook Hollow Industrial District and Park 10 were in fact built on agricultural land, while Tampa Industrial Park was built on an old military base and the source of the land for the Arvida Park of Commerce was not given.

percent for Tampa Industrial Park.

Table I

Multiples By Which Land Prices Increased, Industrial Parks Vs. Surrounding Areas

period	industrial park		surrounding area	
1978-1987[a]	Arvida Park of Commerce	8.8	Palm Beach County	1.9
1954-1962	Brook Hollow Industrial District	10.0	Dallas County	2.1
1978-1987	Park 10	18.0[b]	Harris County	1.9
1956-1962	Tampa Industrial Park	7.5[b]	Hillsborough County	1.8

Sources. Boley (1962), ULI (1988), U. S. Census of Agriculture (various years).

[a]Initial land price for Arvida Park of Commerce reported for "late 1970s".

[b]Based on midpoint of land price range given by Boley or ULI.

It would be unwise to reject this alternative explanation only on the basis of a nonrandom sample of four industrial parks, and clearly more evidence needs to be gathered. In its absence I offer the following argument. The subsidization of early tenants by developers of industrial parks is not in dispute. Developers who wish to bet on exogenous increases in the popularity of the areas in which they invest have available to them the option of pure land speculation. This option must dominate industrial park development since it does not require the investor to incur any losses on seed tenants, hence industrial park development as observed would not take place if this alternative explanation were correct.

A more sophisticated alternative explanation would explain the practice of subsidizing seed tenants. In this view developers compensate early tenants for uncertainty concerning whether the industrial park will deliver the requisite services (e.g., infrastructure and amenities). Satisfactory operation of these early tenants resolves this uncertainty for later tenants who are therefore willing to pay more for land in the park.

Note that this uncertainty does *not* concern whether the industrial park will be fully occupied, since by assumption the tenants receive no benefits from location of other firms within the park (no agglomeration economies are being internalized) and are therefore indifferent concerning its occupancy level *per se*. Nor should this uncertainty concern whether the new site is in fact a lower cost location than the old (holding constant the quality of the development), since presumably the developer cannot know more about this than a firm in the industry in question and thus cannot credibly signal any knowledge in this area.

A test of this alternative explanation might be possible in principle. Some specialized firms have developed many industrial parks in the post-World War Two period, and should have acquired a reputation that would allow them to reduce or eliminate their subsidies to early tenants if the alternative explanation is correct. At present there exists no evidence regarding any relationship between number of prior industrial parks developed and the seed tenant subsidy offered by the developer of a new industrial park. However, one might expect such experienced development firms to come to dominate the market so that seed tenant subsidies would become a less important feature of industrial park development over time, yet there is no indication of this in the trade literature (e.g., compare the discussion of seed tenants in Boley [1962], ULI [1975], and ULI [1988]).

Again I offer an argument in the absence of adequate empirical evidence. Developers of industrial parks must charge later tenants land prices that exceed land acquisition and improvement costs (not to mention promotional costs) in order to recoup their losses on sales to earlier tenants. Despite this added expense to the majority of tenants, in the United States in the post-World War Two period the institution of the industrial park was able to displace (but not eliminate) the previous practice whereby manufacturing firms developed their own sites individually. The success of this new institution is difficult to understand if it merely served to raise costs for most tenants by making them pay for the resolution of uncertainty they could have avoided if they developed their own sites. Indeed, under this alternative explanation industrial parks would inhibit rather than promote development of new, lower cost locations by inserting an unproductive "middleman" into the development process.

IV. Time-phasing of Land Sales and Sequencing of Heterogeneous Firms

In this section I offer tentative explanations for some intriguing but less robust and less well-documented phenomena concerning the land-sale strategies of industrial park developers. Interpreted in the context of my model, these phenomena can shed light on the nature of interfirm externalities. Subsection A addresses time-phasing of land sales and Subsection B addresses preferences regarding sequencing over types of firms. Clearly none of these phenomena can be explained in the framework of Section II where one of N identical firms moves each period in a fixed sequence, so we return to the (implicit) assumption that applied before the introduction of Assumption 7:

Assumption 7′. Firms can move in any period.

We must now confront a problem that occurs when a developer tries to induce more than one firm to move in the same period while practicing perfect price discrimination. To illustrate, suppose the developer chooses to defeat the wait and see strategy and induce all firms to move simultaneously in the first period by setting a land price schedule such that the price in the second and all subsequent periods is sufficiently high to deter any firm from waiting. The problem is that this plan restores the existence of an equilibrium where all firms stay at the old site, since each firm is willing to pay the price to move charged by the developer only on the assumption that all other firms also move. One way to avoid this problem is to suppose that rather than selling the land the developer charges a current value rent in every period t equal to $\pi^*(n^*_{t-1}) - \pi(N)$. This yields the same present discounted value to the developer but from the firm's point of view does not depend on the actions of any other firm. One could also simply assume that the developer sells the land

and is able to use his leadership position to coordinate firms on the efficient equilibrium.[15] Because of the prevalence of land sales and long-term leases in real-world industrial parks, I will use the word "sale" rather than "rent" to refer to land transactions.[16]

A. *Phasing*

Sometimes developers do not offer all of the land available after the seed tenants have made their purchase/lease agreements for sale immediately. Instead the development is "phased" with the expectation that increases in the price of land in the later phases will more than make up for the cost of waiting.[17] Why should a developer have a seed tenant or a phasing policy when he can sell all of his land in the first period?

Intuitively, there are two reasons to suspect that selling all his land in the first period may not be the best the developer can do. First, if learning is especially rapid for the first few firms, it may make sense to sell only a few units of land in the first period because the higher price that firms in the second period will be willing to pay will more than make up for the cost of waiting to receive their payments. This is the intuitive case for selling first to seed tenants. Second, if later firms contribute little to learning, it may make sense to hold some units of land off the market until the second period because the higher price one can charge these firms will more than make up for the slightly lower price one can charge to the firms that come in the first period. This is the intuitive case for the

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[15]A formal analysis of how the developer accomplishes this might view the developer as engaged in "pre-play communication" with firms through his promotional activities for the industrial park. For an example of how (leaderless) pre-play communication can increase the likelihood of coordination on an efficient equilibrium, see Farrell [1987].

[16]This prevalence probably results in part from the fact that in the presence of substantial moving costs a firm that agrees to a renewable short-term rental arrangement is vulnerable to rent hikes by the developer that would make it worse off than if it had stayed at the old site.

[17]Richard Cannon, Vice President in charge of the Irvine Company's Commercial/Industrial Division, states, "Proper phasing of a product can mean absolute dollars in your pocket today. For example, we had a 75-acre, small-lot industrial subdivision, in which each lot was approximately three-quarters of an acre. The project was divided into three phases. In the first phase, the average price per square foot was $3. Eighteen months later, the last phase was concluded at an average price of $6 a square foot" [National Association of Industrial and Office Parks, 1983, p. 14].

developer to sell his land in phases. Both of these arguments depend implicitly on the concavity of $\pi^*(x)$, and thus it seems possible that in the model of this section it will be optimal for the developer to follow both seed tenant and phasing policies, selling a few units of land in the first period and stretching the sale of the remaining units over two or more additional periods.

Given the number of units of land he makes available in each period, the developer again maximizes his profits if he can sell the land in each period at a price equal to the purchasers' expected payoffs. Firms facing this price schedule will be indifferent as to the period in which they move, so a notional excess demand or supply could occur in the land market in some period(s). I assume that if there is excess demand the developer can costlessly ration land so that the rationed firms that make their purchases in a later period are as well off as the firms that were not rationed. Now suppose that notional excess supply occurs. If the developer responds by lowering that period's price by an arbitrarily small amount, all firms now desire to move in that period: no firm chooses to wait because all know that only the planned number of firms will be able to obtain land that period and thus the payoffs to moving in future periods will still not exceed the scheduled prices. If notional demand equals supply, no firm would want to withdraw its offer and wait since its own contribution to learning has already been incorporated into the price to be charged for land next period.

The developer's total profit can now be expressed by the following more general version of (2) above:

(3) $$\Sigma_{t=1}^{\infty} n_t^*[\pi^*(n_{t-1}^*) - \pi(N)]/(1+i)^t,$$

where n_t^* is the number of firms in the industrial park at time t. The difference between expressions (2) and (3) is that in the former $n_t^* = t$ for $0 \leq t \leq N$ and $n_t^* = N$ for $N < t < \infty$. If expression (3) is positive when evaluated at the developer's optimal sales plan we again say that the industrial park is viable. In Rauch (1993b) numerical simulations are used to find these optimal sales plans for a given set of model parameters and three different concave functional forms for $\pi^*(n^*_{t-1})$. In all three cases the developer chooses to provide large subsidies to a small number of firms ("seed tenants") before selling off the rest of his land, and in two cases the remaining land is sold in two "phases".

These results show that, even when an assumption is changed to allow firms to move in any period, for certain parameter values the model can still explain developer subsidization of the first firms or "seed tenants" and subsequent steep escalation of land prices. It should also be noted that the role of the developer in overcoming history when firms can move in any period involves the defeat of a wait-and-see strategy in addition to the subsidization of pioneer firms. Finally, industrial park developers' occasional use of phasing can be interpreted as evidence that (at least some of) interfirm externalities are realized with a lag and that their effects on profits are concave in the number of firms.

B. *Heterogeneous firms*

I argued in the preceding subsection that if the developer has the choice to sell all (or even most) of his land in the first period it is likely that he will not sell the maximum number of units if the profit function $\pi^*(x)$ is strictly concave. It follows that among the set of firms able to move in the first period, some will move sooner and some later. Since in the real world firms are heterogeneous rather than identical, it is then natural to ask whether the model of this section (appropriately extended) predicts that the developer will choose to sell land to certain *types* of firms sooner and certain other types later. I consider two kinds of heterogeneity here: heterogeneity in size and heterogeneity in profit per unit of contribution to learning.

Size heterogeneity. Suppose that size heterogeneity occurs through equal proportionate variation in all relevant firm characteristics, so that when we say one firm is twice as large as another we mean that the values of the profit function, land requirement, and contribution to learning of the larger firm are all double those of the smaller firm. In this case, except for potential problems of indivisibility, there is no reason for the developer to distinguish between firms of different sizes when deciding to which firms he will sell land first.

In the real world it appears that developers typically seek out large firms as seed tenants. Lee and Wong [1958, p. 17] state that it is the policy of developers "to induce nationally prominent firms to become the first tenants" and the continuation of this practice today is confirmed by industry sources [Beyard, 1992]. This policy is easy to understand once one takes account of the fact that promotion is an important part of developers' total costs.[18] Clearly if one wishes to inform firms of the existence and features of a new industrial park (e.g., using direct mail and a follow-up phone or in-person contact), it is cheaper to reach one large firm than two equivalent small firms. It follows that, although the total current value of these promotional costs for the city-industry is fixed, the present value is minimized by advertising to large firms first. Moreover, if the large firm(s) is "nationally prominent" its location in the new industrial park will provide "free advertising" that is more productive, the more firms remain to be attracted to the park. Of course the present value of promotional costs must be deducted from the developer's total profit, making the condition for viability of the industrial park somewhat more difficult to satisfy.

Heterogeneity in profit per unit of contribution to learning. Industrial zoning policy in the United States in the post-World War Two period has become more flexible, allowing developers to add office, commercial, and even residential land uses to the traditional manufacturing and warehousing land uses in industrial parks. Developers of these "business parks" typically reserve the "most valuable" land in the park (which usually means the land most accessible by automobile) for these nontraditional, "higher value" uses, waiting until the park is otherwise built out by traditional uses before selling these parcels [ULI, 1988]. Some of these nontraditional uses clearly do not fit into my modeling

[18] Lee and Wong [1958, p. 20] find for the developers they surveyed that "an aggressive promotional program" for an industrial park accounted for 14 to 28 percent of total costs.

framework because their outputs are nontradeable: hotels and retail centers are good examples of such nonfootloose uses. Office uses, on the other hand, typically include corporate headquarters that produce services that are interregionally and internationally traded.[19] Can we use the model of this section to make sense of the fact that developers typically sell land for office use after selling off the land they have designated for manufacturing use?

One possibility is to think of the N firms as differing in profit per contribution to learning. It is obvious that if the developer is going to choose not to sell all his land in the first period, he would prefer to sell to firms with more profit per externality contribution later, so as to maximize the contribution of early sales to later payoffs and minimize the subsidy component of the early land prices. These firms may also have higher profit per unit land and thus represent "higher value uses", though this is not necessarily the case. The typical behavior of developers of business parks thus makes sense in the context of the model of this section if we think of office uses as having a higher profit per unit of contribution to learning than manufacturing uses. Expressed differently, the model of this section tells us that we can infer from developer behavior that manufacturing produces localized externalities for headquarters services but that the converse effect is weaker. This supports the view of some economists and political scientists that "manufacturing matters" [Cohen and Zysman, 1987], though one would not want to push this point very far without further investigation.

Developers speak of selling the land they have reserved for nontraditional uses after their business parks have "matured" [McCormick, 1992]. In the limit the contribution to learning of these firms is zero, in which case one would not want to sell land to these firms until the period after n^* has equaled or exceeded $\hat{n}^*$ to avoid including any subsidy component in the land price. It thus seems natural to define a park as "mature" in period t

[19] For a model of international trade in corporate headquarters services see Helpman [1984].

if $n^*_{t-1} \geq \hat{n}^*$. One can then imagine recasting the analysis of city-industry relocation in this paper into a model of the establishment of a tradeable "base" activity for a new city. Once the base "matures", nontradeable activities grow, and the ultimate size of the city is limited only by congestion diseconomies.

V. Conclusions

This paper has argued that in the post-World War Two period history affects city-industry location by creating a first-mover disadvantage that can prevent relocation from an old, high-cost site to a new, low-cost site. It has demonstrated that developers of industrial parks can partly overcome this inertia through discriminatory pricing of land over time, and has provided empirical evidence that they do in fact engage in such behavior. Finally, the paper has shown how other aspects of developer land-sale strategy can be a source of information on the nature of interfirm externalities. Empirical work in this area is urgently needed.

A major theme of recent growth theory is that growth at the national level is driven by investments in knowledge and other capital by forward-looking firms. This paper shows that growth (or shrinkage) at the local level can be driven in part by these same firms' responses to incentives offered by forward-looking developers, who are themselves making investments in land. Just as recent papers on growth at the national level show how national government policy can affect the growth rate, this paper shows how local growth can be influenced by local government policy. Zoning policy in particular was singled out for a fresh look, with an eye to its role in conferring monopoly power on developers that permits them to practice price discrimination.

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