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Technology and the Life Cycle of Cities

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During times of major technological change, leading cities are often overtaken by upstart metropolitan areas. Such upheavals may be explained if the advantage of established urban centers rests on localized learning by doing. When a new technology is introduced, for which this accumulated experience is irrelevant, older centers prefer to stay with a technology in which they are more efficient. New centers, however, turn to the new technology and are competitive despite the raw state of that technology because of their lower land rents and wages. Over time, as the new technology matures, the established cities are overtaken.

Keywords: technological changes, urban system, geographical concentration

JEL classification: O3, R3

In his magisterial survey of urban history, Bairoch (1988) has noted that periods of revolutionary technological change are often marked by “upheaval in the urban hierarchy”: old cities that remain locked into traditional industries are shouldered aside by upstart cities that embody the new. In time, of course, these upstarts are themselves often shouldered aside by yet newer urban centers. In some cases, cities—not huge diversified cities like London and Paris, but smaller cities with narrower export bases—appear to go through a life cycle of growth and decay.

This rise of cities is evidently driven by circular causation, in which success reinforces success via some kind of external economy. Such external economies in some form underlie all models of urban systems, such as the classic work of Henderson (1974) and some of our own more recent work (Krugman, 1991). But why do cities decline? Episodes of decline could represent no more than entropy: sooner or later, something is bound to come along that disrupts the virtuous circle of urban success. Yet it is hard not to suspect that there is some more fundamental process at work, one in which industrial development at some point occurs preferentially in new centers rather than old, established ones. That is, it seems plausible that there is a natural life cycle of urban rise and decline.

This article offers one story about such a natural life cycle, a story that is rooted in a simple model of technological change that we have already applied to the question of cycles in *national* technological leadership (Brezis, Krugman, and Tsiddon, 1993). The story is based on the assumption that the key external economies that support urban development are learning effects associated with the geographical concentration of industry. As long as the technology of an industry undergoes “normal” progress that builds on previous ideas, the interchange of knowledge among entrepreneurs and workers concentrated at an established industrial center will tend to preserve that center’s leadership. From time to time, however, new technological ideas arrive that are discontinuous with those that came before. Such technical changes offer the possibility of industry relocation because for the new technologies the accumulated experience of existing industry concentrations may be of little value; meanwhile, existing industry concentrations present difficulties for new firms. Precisely because of their previous success, they are likely to be characterized by high land rents, prices, and wages. During periods of normal technological change these disadvantages are outweighed by the advantages of knowledge spillovers, but when a major technological shift occurs, this “centripetal” force is weakened. The result then is that new technologies tend to be exploited in new centers. As the new technologies become increasingly productive, these new centers eventually outstrip the old.

Although we have, as already indicated, developed this story in a previous paper focused on cycles of national leadership, we believe that the story is considerably more compelling as an empirical matter when applied to cities, for at least four reasons. First, where the role of external economies in national economic advantage is debatable, few would question that they play a central role in urban economics. Second, even large cities are far more specialized (at least in their “base” industries—that is, those that do not cater only to local residents) than all but the smallest nations. Thus the chance that it will be locked in to the wrong technology is much greater for a whole urban economy than it is for a nation. Third, because they must compete for labor and capital, cities within a nation are engaged in much more of a zero-sum competition with each other than nations are. Finally, when a city loses such a competition, the consequences are much more dramatic than they are at the national level; as we describe below, episodes of actual population decline, sometimes quite radical, are common in urban history.

Unfortunately, while the justification for applying a leapfrogging story is probably greater for the case of urban than for that of national development, the urban case presents considerably more complex modeling challenges. In particular, it is somewhat unclear how to think about the *disadvantages* of existing cities and the reasons that such established centers do not themselves shift immediately to new technologies. These questions are closely related. If old centers do not immediately adopt new technologies, it must be because from their point of view the new is inferior to the old; if new centers are nonetheless able to enter the marketplace with these new technologies, it must be because any initial inferiority of the new techniques is offset by the advantages of not being required to produce in an established center. In other words, to make the argument clearly we must pay careful attention both to the specifics of technological change and to the negative effects of urban concentration.

The remainder of the article is in four parts. We begin with a brief description of several historical episodes in which established industrial centers seem to have been stranded by the emergence of new technologies. We then set out a simple general-equilibrium von Thünen-type model of an urban center. After determining short-run equilibrium for an individual urban center of given population, we set up a dynamic framework under which a new technology will be exploited by a new urban center, leading to the decline of the established center.

1. Technological Change and Urban Decline

Examples of the decline of urban centers when their special technological competence becomes outmoded are quite common. Here we review two striking examples, one form the dawn of modern industrialization, and one occurring at the time of writing. Some relevant data on urban populations are summarized in Table 1.

Table 1. The rise and fall of cities (population in thousands).

a. Fall of cities in Holland (specializing in textile)

	1600	1700	1750	1800
Leiden	44	65	37	31
Haarlem	39	37	27	22
Amsterdam	54	200	210	217

b. Rise of new cities in England (specializing in cotton)

	1700	1750	1800	1850
Manchester	8	18	84	303
Birmingham	7	24	71	233
Sheffield	3	12	46	135
London	575	675	948	2236

c. Fall of cities in the United States (specializing in steel)

		1900	1950	1970	1990
Pittsburgh	(City)	321.6	676.8	520.1	369.8
	(MSA)			2684	2395
Gary	(City)	16.4	133.9	175.4	116.6
	(MSA)			633	605
Youngstown	(City)	44.8	168.3	140.9	95.7
	(MSA)			645	601
U.S.		76212	151325	203211	248709
	(Metropolitan)			139419	197824

Sources: Bairoch, Batou, and Chevre (1988); *U.S. Historical Statistics of the States* (1993), *U.S. Statistical Abstract* (1995).

Note: The U.S. Census now calculates population not only for political units but for several broader definitions of metropolitan areas. We show these broader data for the available dates.

1.1. Textiles in the Early Industrial Revolution

Prior to the rise of the factory system, the European textile industry was essentially focused on woolens. Spinning and weaving were largely rural activities, carried out in particular by English producers under a putting-out system. However, the finishing and dyeing of fabric was concentrated in urban centers and was dominated in particular by the Dutch cities of Haarlem and Leiden.

These cities failed, however, to take part in the great eighteenth-century shift to cotton, based on mechanized spinning. Between 1700 and 1795 Leiden's production of woolen pieces declined 94 percent (Posthumus, 1939). The population of Leiden declined over the century from 65,000 to 31,000; Haarlem declined from 37,000 to 22,000. There is little doubt that technology was the villain, as Mokyr (1976, p. 4) remarks: "Technological changes abroad were largely responsible for the decline of Dutch manufactures." That is, the special expertise that had allowed Leiden and Haarlem to have lower costs than potential rivals elsewhere in Europe despite high Dutch wages was no longer useful given the new technology; advantage shifted to English textile centers, especially Manchester.

Notice, incidentally, that this urban decline was specific to textile centers. Although Holland did lag behind English economic growth, other Dutch cities such as Amsterdam continued to gain population.

1.2. A Modern Example: Steel

Beginning in the 1960s and accelerating after the mid-1970s, the U.S. steel industry experienced a major shift. This was partly the result of the displacement of steel by other materials in the manufacture of consumer durables and partly the result of increased import penetration. There was also, however, a shift in the technology of steel production itself. The traditional large, integrated steel mill, which converted coke and iron ore to steel via a blast furnace or open hearth, was increasingly displaced by so-called minimills, electrical smelters relying largely on scrap for raw materials (see Hogan, 1987). Between 1975 and 1987 the number of integrated steel mills in the United States declined from 47 to 24; meanwhile 50 minimills were opened.

Integrated steel production had been concentrated in a relative handful of major centers. Minimill output is in general less concentrated, as it tends to follow the sources of scrap; but to the extent that new centers did arise, they tended to be in new areas, with the existing centers attracting very few of the new plants.

The result, as shown in Table 1, has been a decline of those urban areas strongly dependent on steel. Indeed, most of the U.S. metropolitan areas to have experienced an actual decline in population over the period 1970 to 1990 (a period over which the overall metropolitan population grew by 41 percent) were steel centers, including major metropolitan areas such as Pittsburgh and, even more strikingly, smaller one-industry centers such as Youngstown.

These examples suggest that the phenomenon of urban decline due to emergence of a new technology, which devalues previously important technological competence, is an important reality. In the remainder of the article we turn to a formal model intended to represent that process in a stylized way.

2. Assumptions of the Model

We consider an economy with a given labor force L, which produces and consumes two types of goods—food, a technically stagnant good with a constant-returns technology, and manufactures, a set of technically progressive goods subject to localized learning effects. We refer to individuals employed in the production of manufactures as workers and assign them numbers 0 to $m-1$. Those employed in the production of food will be referred to as farmers and assigned the numbers from m to L. Allocation of the labor force between farmers and workers is endogenously determined as to equate their real income. (We ignore the integer constraints and treat the distribution of labor as a continuous variable).

This is a spatial economy organized into one or more *city-regions*. A city-region consists of a central business district or downtown surrounded by a food-supplying agricultural hinterland. It is assumed that manufactures production within such a city-region must take place within the central business district in order to take advantage of the knowledge accumulation from past production. Workers live downtown, and we ignore any possible use of land for residential purposes.[1] We assume that we start with one city for simplifying matters, although a large population could sustain a multiple-city equilibrium.

Farmers are assumed to live on their farms, transporting food to the central business district for sale and buying there the manufactured goods they desire. We also imagine a rather passive class of landlords, who remain in place with their land and spend their rental income *in situ*.[2]

Food is subject to transportation costs that are an increasing function of the distance to the central business district. Given competition among farmers, what must emerge is a land rent gradient that just offsets the advantage of better access.

Finally, we simplify the geometry by making the city-region one-dimensional, with residential and agricultural land arrayed along a line of unit width.

2.1. The Agricultural Sector

We begin with the agricultural sector. Farmers are distributed across the hinterland; we label them so that individual m is closest to the center, individual L farthest. Each farmer has one unit of labor, which he uses to produce food with a fixed-coefficient production function; we choose units so that one unit of food is produced by one unit of land and one farmer:

$$Y_f = \min(L_f, T). \tag{1}$$

Given this production function, each farmer will rent one unit of land and produce one unit of food. We assume that the utility function of each farmer takes a Cobb-Douglas form:

$$U(Q_{mj}, Q_{fj}) = Q_{mj}^{\beta} Q_{fj}^{1-\beta}, \tag{2}$$

where Q_{mj} and Q_{fj} are the consumption of manufactures and food respectively by farmer j.

Each farmer consumes part of his own production; the rest he sells at the central business district, using the proceeds to buy manufactures. To calculate the budget constraint of a typical farmer, we must take into account the costs of getting food to market. Transportation costs will be assumed to take Samuelson's "iceberg" form, in which part of any food carried to the center is lost en route. Let D_j be the fraction of a unit of food sent to market by farmer j that actually reaches the central business district; D_j will be a decreasing function of the farmer's distance from the center and for simplicity will be assumed to involve a decay rate of δ per unit distance:

$$D_j = e^{-\delta(j-m)}. \tag{3}$$

The budget constraint of farmer j will take the form

$$p_m Q_{mj} + p_f D_j Q_{fj} = p_f D_j - R_j \equiv E_j, \tag{4}$$

where p_m is the price of manufactures and p_f the price of food, both measured at the city center, and R_j is the land rent paid by that farmer. E_j is the income of farmer j, including the imputed value of the food he grows for himself.

Rents are determined by the requirement that all farmers have equal welfare. Let E_L be the income of the most distant farmer; then we must have

$$E_L/(p_m^\beta p_f^{1-\beta} D_L^{1-\beta}) = E_j/(p_m^\beta p_f^{1-\beta} D_j^{1-\beta}). \tag{5}$$

Suppose for simplicity that the most distant farmer pays no rent; his income is simply $p_f D_L$. Substituting back into equations (4) and (5) we therefore find that the utility of each farmer is

$$U_F = \frac{\gamma p_f D_L}{p_m^\beta (D_L p_f)^{1-\beta}} = \gamma D_L^\beta p_f^\beta p_m^{-\beta}, \tag{6}$$

where $\gamma = \beta^\beta (1-\beta)^{1-\beta}$. The rent equation is[3]

$$R_j = p_f D_j [1 - (D_L/D_j)^\beta]. \tag{7}$$

Finally, we determine food consumption in the agricultural sector. Here we need to take account of the consumption of both farmers and landowners. Bear in mind that we are assuming that landowners reside on their land. Thus all income generated at a given location j is divided between landowners and farmers, each of whom spends a fraction $1-\beta$ of income on food. Thus β units of food per unit of land are available for shipment to the urban center. Therefore, the net supply of food to the city S_f is

$$S_f = \beta \int_m^L D_j \, dj = \frac{\beta}{\delta}(1 - e^{-\delta(L-m)}). \tag{8}$$

2.2. The Manufactures Sector

We assume that the accumulated knowledge that makes the city an efficient place to produce manufactures is available only at the central business district and that all manufactures production therefore takes place there.

Each worker is assumed to have one unit of labor. At any given time we let a be the productivity of manufacturing labor, which is predetermined at any point of time.[4] The output of worker i, Y_{mi}, is

$$Y_{mi} = a. \tag{9}$$

Workers consume manufactures and food and share the same utility function as farmers. The budget constraint of a worker is

$$p_m Q_{mi} + p_f Q_{fi} = p_m a \equiv E_i, \tag{10}$$

and his utility is therefore

$$U_M = \gamma \frac{E}{p_m^{\beta} p_f^{1-\beta}} = \gamma a p_m^{1-\beta} p_f^{\beta-1}. \tag{11}$$

Finally, all workers will have the same consumption pattern, with the consumption of food per worker equaling

$$p_f Q_{fi} = (1-\beta)E_i = (1-\beta)a p_m. \tag{12}$$

3. Short-Run Equilibrium

Given the labor force L and the productivity of manufacturing workers a, it is straightforward to determine the equilibrium allocation of land and labor, together with the implied land rents. It will be convenient at this point to adopt manufactured goods as our numeraire (and setting the price of manufactures to 1), since these goods are assumed to be costlessly transported and hence have the same price everywhere.

Short-run equilibrium requires the clearance of the good market, and that individuals have no incentives to reallocate themselves between the two sectors. Hence, equilibrium requires that two conditions be satisfied. First, the real income of farmers and workers must be equalized (equations (6) and (11)), implying

$$D_L^{\beta} = a/p_f. \tag{13}$$

Since equation (3) implies that m and D_L are positively related, (13) defines a downward-sloping relation between p_f and m, depicted as UU in Figure 1.

The second equilibrium condition is market-clearing for food. Given equation (12), the total food demand of all m workers in the city D_f is

$$D_f = (1-\beta)\frac{ma}{p_f}. \tag{14}$$

The market equilibrium condition (that is, equating the net supply of food, equation (8), and the demand of food, equation (14)), is therefore

$$\frac{\beta}{\delta}\left(1 - e^{-\delta(L-m)}\right) = (1-\beta)m\frac{a}{p_f}. \tag{15}$$

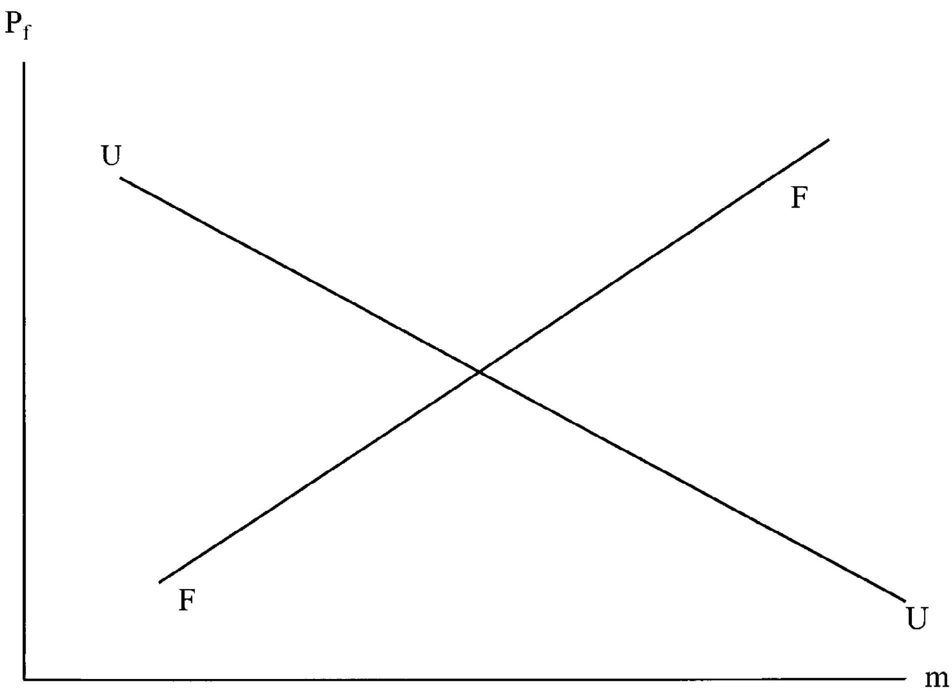

Figure 1. Equilibrium allocation of labor and relative price of food.

Thus (15) defines an upward-sloping schedule for p_f and m, shown as *FF* in Figure 1. The intersection of *FF* and *UU* determines the equilibrium allocation of labor and relative price of food.

It will be useful to examine how this equilibrium and the utility of each individual are affected by changes in two parameters: the productivity of manufacturing labor a and the size of the labor force L. Since in both (13) and (15) the parameter a enters in the form a/p_f, it is straightforward to establish that an increase in a is matched by an equal rise in the relative price of food, with no change in the spatial structure of the city-region.[5] Hence, it follows from (11) that the welfare of all individuals rises in the same proportion: a 1 percent rise in a produces a β percent rise in utility for workers and farmers alike.

Next, an increase in L reduces the real income of the typical individual. Indeed, note that from (11), the utility of a worker is negatively related to p_f, so it is sufficient to show that an increase in L raises p_f.

Graphically, from equation (13), we see that for a given p_f, an increase in L, leads to an equal increase in m, and therefore *UU* shifts right by precisely the increase in L. In equation (15), an equal increase in L and m will leave the left side unchanged, but the right side will also increase. Therefore, to stay in equilibrium, the rise in m has to be smaller than the rise

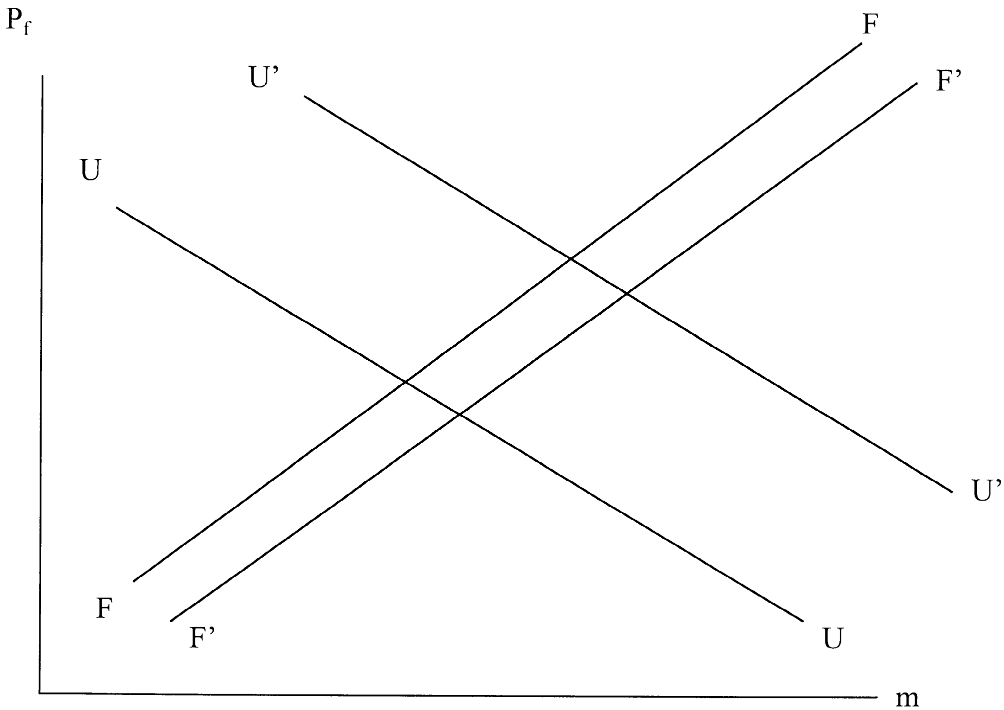

Figure 2. Effects of an increase in the labor force on the equilibrium.

in L, and *FF* shifts by less than the increase in L.[6] Thus the effect of an increase in L is as shown in Figure 2: both *FF* and *UU* shift right, to $F'F'$ and $U'U'$, respectively, but because *UU* shifts more, p_f rises and therefore the utility of the representative worker declines. (Intuitively, a larger city must draw its food from a larger hinterland, implying higher food prices and hence, other things being the same, lower utility. We could derive a similar result by instead assuming that workers require land to live on and by making commuting costly or, for that matter, by combining the two diseconomies of city size, without changing the model's implications.)

The implication of these two results is that the utility of the representative individual in a city-region, whether worker or farmer, may be described by a function that is increasing in the productivity of manufacturing workers and decreasing in the city-region's population:

$$U = U(a, L). \tag{16}$$

4. Dynamics of Technical Change

We now introduce the dynamics of technical change. Technology is assumed to progress in two ways. First, within a technological generation there is steady learning based on local experience. Second, there are occasional major technical changes in which new methods are introduced for which previous experience is irrelevant.

Within a technological generation, productivity is an increasing function of cumulative experience within a city:

$$a = a(K(t)), \tag{17}$$

where $K(t)$ is the cumulated manufacturing output produced in the city from time 0 to time t:

$$K(t) = \int_0^t \int_0^m Y_{mi}(\tau)\, di\, d\tau. \tag{18}$$

Notice that since K is a stock variable, we assume that a is given at each point in time—that is, in continuous time, current manufacturing output can be regarded as infinitesimal relative to the stock.

We assume that the learning function $a(.)$ takes a logistic form:

$$a = \Gamma \frac{e^{\nu K}}{e^{\nu K} + \mu}. \tag{19}$$

This particular form has some plausible and also useful properties. Productivity is nonzero even with no experience in a new technology: $a(0) = \Gamma/(1 + \mu)$. Productivity then rises with experience; but it does so at a diminishing rate, with a approaching a limit of Γ. If a technology has been in use for an extended period and has become "mature," there will therefore be little opportunity for continued learning.

Now consider the following situation. An established manufacturing center has accumulated experience to the point that its technology is mature, so that there is little room for further learning. Then a new technology is introduced. It may represent a new way of producing the same manufactures or a new kind of manufactures. If the latter is the case, we assume for simplicity that the new good is a perfect substitute for the old, so that we can think of simply introducing a new learning schedule $a^*(K^*)$, where K^* is cumulative experience using the *new* technology. That is, past experience is irrelevant.

We assume that the new technology is potentially superior, in the sense that $a^*(x) > a(x)$ for any x: for any given amount of relevant experience workers using the new technology will be more productive. A simple way to do this is to suppose that the function in (19) has a higher Γ in the case of the new technology.

Despite this potential advantage, for the established center the new technology is initially inferior to the old:

$$a^*(0) < a(K). \tag{20}$$

Finally, we assume that while initially inferior to the old technology, the new technology is good enough that in a city-region with small population and thus low rents and costs of

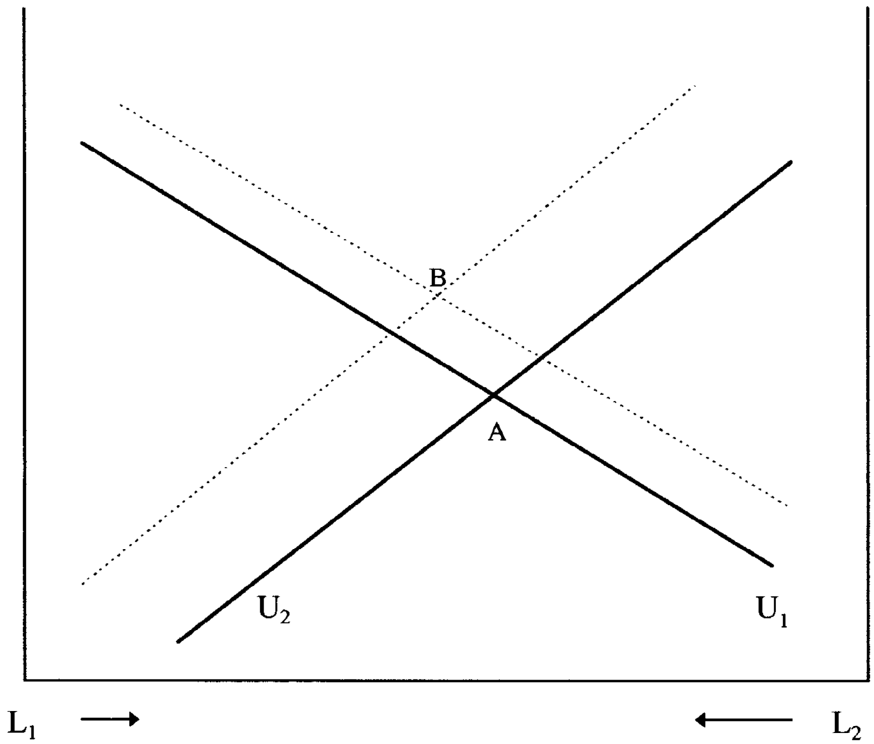

Figure 3. Inter-city allocation of the labor force.

transportation, it allows a higher utility than that in the established center:

$$U(a^*(\varepsilon), \varepsilon) > U(a(K), L) \qquad (21)$$

for ε near zero.

Given these assumptions, we can immediately see what happens. When the new technology becomes available, producers in the established center do not adopt it because given their experience they remain more productive with the old technology. A new, smaller center comes into being, however, because the new technology is good enough to compete with the old given the extra advantage of low transport costs.[7] The relative sizes of the two city-regions will be determined by the necessity of equal utilities. Let L^1 be the labor force of the old center, L^2 that of the new center. Then equilibrium may be represented in Figure 3 by point A in which U^1 and U^2 represent the utility of typical workers in each location as a function of the city-region's labor force: population will move to equalize welfare of individuals in the two centers.[8]

Over time, as the productivity of workers rises through learning in both locations, both schedules in Figure 3 will shift up. If the old technology is sufficiently mature, however,

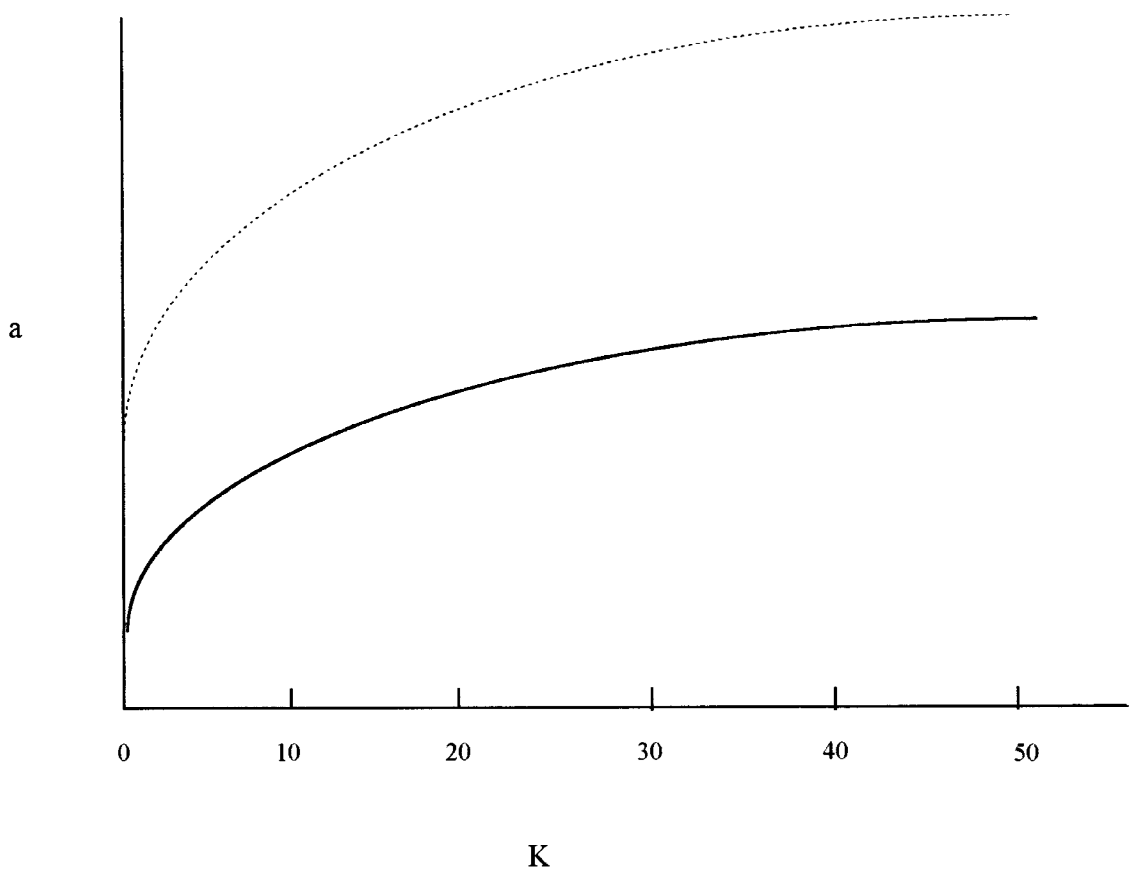

Figure 4. Dynamics of technical change.

technical progress will be slow regardless of the level of output, so a^* will rise more rapidly than a. Recall that it was established previously that welfare for a given L is homogeneous of degree β in a; a rise in a^*/a implies that U^2 will rise more than U^1, as illustrated in Figure 3 point B, so that over time the existing center will decline and the new center gains population at its expense.

It may be helpful to illustrate these points with a numerical example. For that example we assumed the parameter values $\beta = .5$, $\delta = .5$, $\nu = .1$, $\mu = 1$. We set the total labor force at 5, and assumed $\Gamma = 1$ for the old technology, 1.5 for the new.

Figure 4 shows equation (17) for the old and new technologies, respectively. The new technology is potentially superior to the old but is inferior from the point of view of producers in a city with sufficient experience in the old technology. We consider a situation in which the

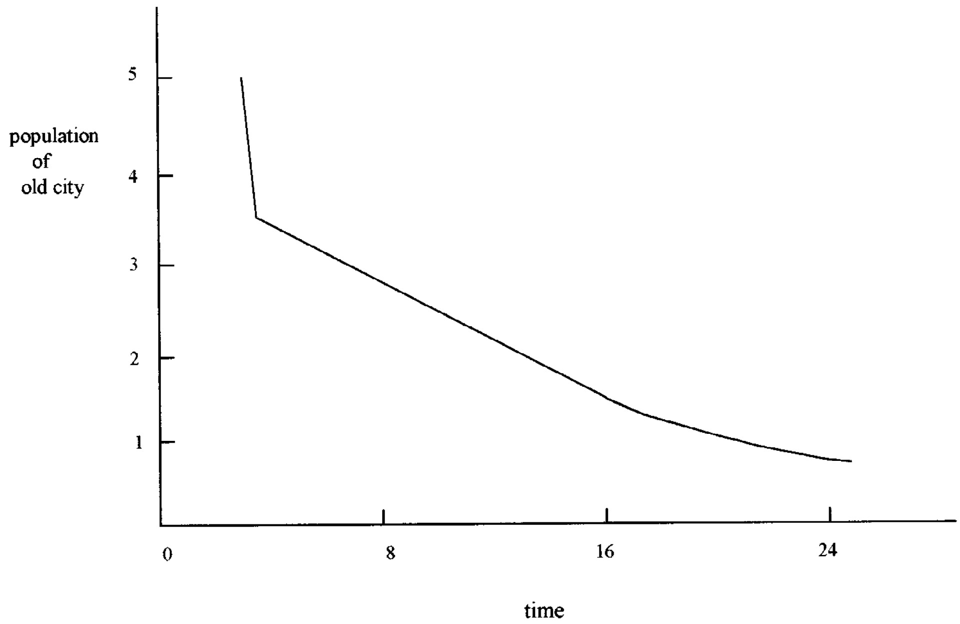

Figure 5. Dynamics of the old city labor force.

existing city has achieved sufficient experience to put it close to the maximum productivity level given that technology—that is, $K = 40$.

What happens when the new technology becomes available? The existing city does not adopt it, but a smaller new city using that technology first emerges, then gradually grows at the original city's expense as it gains experience. Figure 5 shows how the labor force of the original city evolves over time. (At each step the general equilibrium of each city-region was solved, and labor allocated between the two cities so as to equalize utility; the implied output was then used to update K in each city, and the new implied levels of productivity were used in the next step). On the introduction of the new technology there is a step drop in the original city's population, then a progressive further decline as the new city's relative productivity increases with learning.[9] This is precisely the story we sketched out in the article's introduction.

5. Conclusion

This article offers a simple model that may explain the existence of a natural life-cycle for urban centers, suggesting that the very success of an urban center in a traditional technology may put it at a disadvantage in the implementation of a newer, ultimately more productive new technology. The model thus provides a rationale for grand cycles of urban rise and decline, suggesting that they are not simply matters of historical accident but may reflect a deeper underlying logic.

It is clearly possible to make the basic model more realistic by adding realistic complications such as the use of land for residential purposes and the cost of commuting, as well as other external economies both positive and negative. What we particularly hope, however, is that this article may serve as a spur to empirical research into the rise and fall of cities. To confirm the importance of technology over the life cycle of cities requires a more detailed examination of the actual history of both cities and the technologies on which they depended. Bairoch, Batou, and Chevre (1988, p. 269), in their book compiling data on cities, wrote: "There is a need to add facts on social and economic factors to our data on cities. This will assist us in understanding the main factors behind the different evolution patterns of city populations." A preliminary overview of the historical evidence suggests, as we indicated in Section 1, that endogenous life cycles are an important aspect of urban history.

Acknowledgments

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Notes

1. If we did introduce residential land requirements, the disadvantages of city size would also include commuting costs. However, the basic analysis would be unchanged, providing that farming is relatively more land-intensive than manufacturing.
2. The problem of modeling where landlords spend their income is a nuisance in all urban models. Many models simply assume that rental income is spent elsewhere; however, we prefer to use this alternative fixup, originally introduced in Fujita and Krugman (1995), in order to keep the general equilibrium character of the analysis complete.
3. If we had a land requirement for workers, the rent curve for the residential area would be tied down by the requirement that the rent of the most distant commuter would be equal to the rent of the *least* distant farmer.
4. The productivity of manufacturing, a, is an increasing function of cumulative manufacturing output produced in the city. So as shown in the dynamic analysis, Section 4, a will be determined endogenously as a function of past output.
5. The fact that m is unaffected by an increase in a is an artifact of Cobb-Douglas preferences.
6. Differentiating equations (13) and (15), we find that

$$\frac{\partial p_f}{\partial L} = \frac{-\beta^2\delta e^{-\delta\beta(L-m)}e^{-\delta(L-m)} + \beta\delta e^{-\delta\beta(L-m)}\left[(1-\beta)\frac{a}{p_f} + \beta e^{-\delta(L-m)}\right]}{\beta\delta e^{-\delta\beta(L-m)}(1-\beta)\frac{ma}{p_f^2} + \left[(1-\beta)\frac{a}{p_f} + \beta e^{-\delta(L-m)}\right]\frac{a}{p_f^2}}.$$

Since the denominator is positive the sign of the derivative is the same as that of the numerator, which is equal to

$$S = \delta(1-\beta)\frac{a}{p_f}e^{-\delta(L-m)} \geq 0.$$

7. Where will the new center be located? In general, given our assumptions, this is indeterminate; all that we can say is that the new central business district will be at least as far away from the existing one as the last farmer just before the innovation, because the incentive is always to choose a location with zero land rents and a minimal price of food. We might invoke very small advantages of being close to the existing center to propose that the new center will be located precisely at that agricultural margin; but in any case this plays no role in the story.
8. If we assume that manufactures are tradeable between cities, workers in the new city will receive a lower nominal wage than those in the established center; that is why the new city is competitive despite its lower productivity. The *real* wage is equalized because the price of food is lower in the smaller city.
9. In our numerical example the old city at the end of the process tends to 1, and the new city to a population of 4. Old cities do not necessarily disappear. However, we could have chosen parameters under which the old city would indeed have vanished.

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