CHAPTER 3

Why Do Firms Cluster?

People don't go there anymore. It's too crowded.

—YOGI BERRA

If two firms compete for customers in a region, will they locate close together or far apart? It is natural to imagine that the two firms will split the region into two halves, giving each firm a local monopoly. That's what happened in the theoretical models of Chapter 2, and it happens for many firms in the real world. Yet all sorts of competing firms locate close to one another, including carpet producers in Georgia and television producers in Los Angeles. Why?

This chapter explores agglomeration economies, the economic forces that cause firms to locate close to one another in clusters. The forces acting on firms in a single industry together are called localization economies, indicating that they are "local" to a particular industry. For example, firms in the software industry cluster in Silicon Valley. When agglomeration economies cross industry boundaries, they are called urbanization economies. The idea is that the presence of firms in one industry attracts firms in other industries. For example, the corporate headquarters of different industries cluster in cities. Urbanization economies lead to the development of large, diverse cities. As we'll see, localization and urbanization economies have common roots.

Before we explore the reasons for localization economies, it will be useful to look at some facts on industry clusters in the United States. Table 3–1 shows the facts on employment clusters for six industries. In the production of aircraft engines, the four metropolitan areas listed (Hartford, Phoenix, Cincinnati, and Indianapolis) contain nearly half of U.S. employment in the industry. Firms producing biopharmaceuticals cluster in New York, Chicago, Philadelphia, and San Francisco, while firms producing software cluster in Seattle, the San Francisco Bay Area, and Boston. Among the small metropolitan areas with relatively large clusters of software employment are Austin, Texas, and Raleigh, North Carolina. Bloomington, Indiana, has over a fifth of national employment in the production of elevators and moving stairs, while Los Angeles has over two-fifths of national employment in video production and distribution.

TABLE 3–1 Select Industrial Clusters in U.S. Metropolitan Areas, 2004

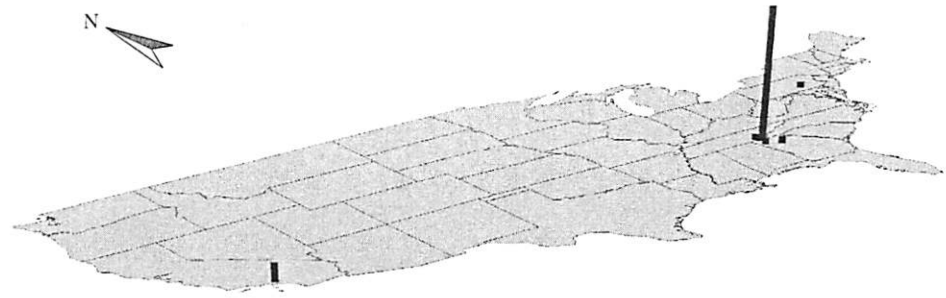
Product	Metropolitan Area	2004 Employment	Nationwide Employment (%)
Aircraft engines	Hartford, CT	15,619	22.67
	Phoenix, AZ	7,500	10.89
	Cincinnati, OH	6,957	10.10
	Indianapolis, IN	4,045	5.87
Biopharmaceutical products	New York, NY	51,604	27.21
	Chicago, IL	19,754	10.42
	Philadelphia, PA	11,383	6.00
	San Francisco, CA	10,706	5.65
Computer software	Seattle, WA	36,454	11.10
	San Francisco, CA	31,353	9.54
	San Jose, CA	29,221	8.89
	Boston, MA	23,415	7.13
Elevators and moving stairways	Bloomington, IN	1,750	20.03
	New York, NY	1,170	13.39
Financial services	New York, NY	427,296	12.97
	Chicago, IL	151,499	4.60
	Los Angeles, CA	142,337	4.32
	Boston, MA	133,342	4.05
Video production and distribution	Los Angeles, CA	161,561	44.00
	San Francisco, CA	28,394	7.73
	New York, NY	27,541	7.50

Source: Author's calculations based on data from Cluster Mapping Project, Harvard Business School.

Of course, not all industry clusters occur because of agglomeration economies. We saw in the previous chapter that beet-sugar production facilities are concentrated in beet-growing areas. Similarly, employment in the tobacco-products industry is concentrated in tobacco-growing areas: North Carolina has about 31 percent of national employment in the industry. For the hospitality and tourism industry, two clusters occur in cities with legalized gambling (Las Vegas and Atlantic City).

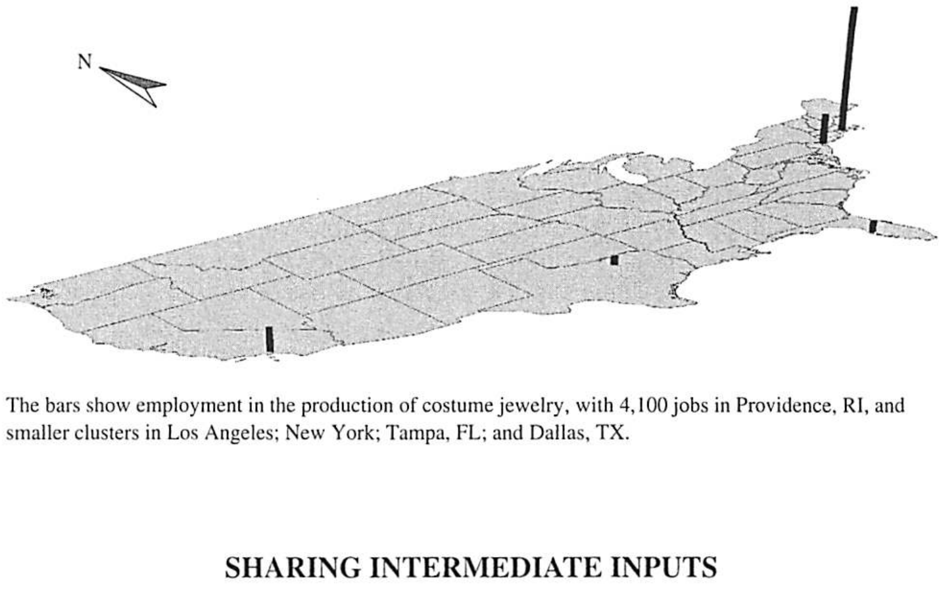
Maps 3–1 and 3–2 show the locations of job clusters of two industries. Each vertical bar shows the number of jobs in a particular industry in a specific metropolitan area. In Map 3–1, the bars show the job clusters for the carpet and rug industry, which is concentrated in the area around Dalton, GA, home to almost 17,000 jobs in the industry, or 41 percent of the industry's nationwide employment. There are smaller clusters nearby in Atlanta and Chattanooga, and more distant clusters of 2,300 jobs in Los Angeles and 750 jobs in Harrisburg, PA. Map 3–2 shows the job clusters for the production of costume jewelry. The bars show employment clusters for the costume-jewelry industry, which is concentrated in Providence, RI (4,100 jobs, or 55 percent of national employment), with smaller concentrations in New York, Los Angeles, Tampa, and Dallas. For additional maps of employment clusters, visit the Web site of the book.

MAP 3–1 Job Clusters: Carpets and Rugs



The bars show employment in the production of carpets and rugs, with 16,790 jobs in Dalton, GA, and smaller clusters in Los Angeles; Atlanta; Chattanooga, TN; Harrisburg, PA; and Rome, GA.

MAP 3–2 Job Clusters: Costume Jewelry



The bars show employment in the production of costume jewelry, with 4,100 jobs in Providence, RI, and smaller clusters in Los Angeles; New York; Tampa, FL; and Dallas, TX.

SHARING INTERMEDIATE INPUTS

Some competing firms locate close to one another to share a firm that supplies an intermediate input. The conventional list of production inputs includes labor, raw materials, and capital (machines, equipment, structures), but usually ignores intermediate inputs. An intermediate input is something one firm produces that a second firm uses as an input in its production process. For example, buttons produced by one firm are used as inputs by a dressmaking firm. The classic example of a cluster motivated by sharing an intermediate input is a cluster of dressmakers around a buttonmaker (Vernon, 1972).

Dresses and Buttons

Consider the production of high-fashion dresses. The demand for dresses is subject to the whims of fashion, so the dressmaking firms must be small and nimble, ready to respond quickly to changes in fashion. The varying demand for dresses causes varying demands for intermediate inputs such as buttons. A dressmaker's demand for buttons changes from month to month, not in the quantity demanded, but in the type of buttons demanded. One month the dressmaker might use square blue buttons with a smooth finish and the next month round pink buttons with a rough finish.

Consider next the production of buttons, the intermediate input. The production technology for buttons is summarized in three assumptions. The first is one of the axioms of urban economics:

Production is subject to economies of scale

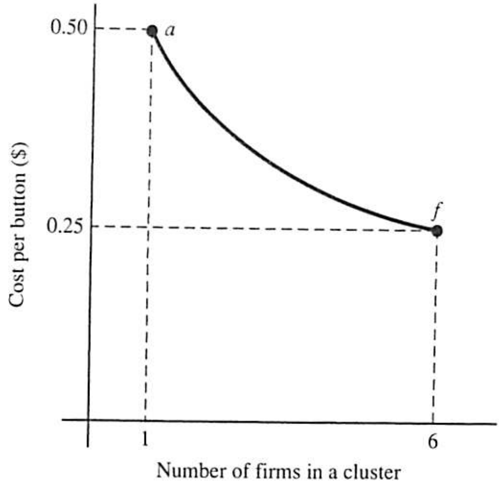
Because button producers use indivisible inputs and specialized labor, the cost per button decreases as the quantity increases. The scale economies are large relative to the button demand of an individual dressmaker, so dressmakers won't produce their own buttons but will buy them as intermediate inputs from button producers. There are two other assumptions in the dress-button model:

- **Face time.** A button for a high-fashion dress is not a standardized input that can be ordered from a catalog or a Web site, but requires interaction between dressmaker and buttonmaker to design and produce the perfect button for the dress of the month. The face time means that a dressmaker must be located close to its button supplier.
- **Modification cost.** Once a dressmaker buys a button from a buttonmaker, the dressmaker may incur a cost to modify the button to make a perfect match. For example, the dressmaker might have to shave the edges of a square button to make it a hexagon.

Figure 3–1 shows the average cost of buttons from the perspective of the dressmaker. Point *a* shows the cost for an isolated dressmaker, which has a relatively high button cost for two reasons. First, the buttonmaker produces for a single dressmaker, so output will be relatively low and the average cost (and price) of buttons will be relatively high. Second, the buttonmaker produces just one type of button (e.g., square buttons), so the dressmaker's modification costs will be relatively high. When the dress of the month calls for square buttons, modifications won't be necessary, but in all the other months, the dressmaker incurs a modification cost.

A dressmaker in a cluster has lower button costs for two reasons. First, a cluster of several dressmakers will generate sufficient button demand to allow buttonmakers to exploit scale economies, leading to lower button prices. Second, the larger total demand for buttons will allow buttonmakers to specialize in different varieties of buttons, reducing the modification costs of dressmakers. In a cluster, a dressmaker might be able to choose from buttons that are squares, hexagons, or triangles. In Figure 3–1, the average cost (and price) of buttons drops from \$0.50 for an isolated

FIGURE 3–1 Clustering and the Average Cost of Intermediate Inputs



An isolated firm has a relatively high unit cost of buttons (point *a*). As the number of dressmakers in a cluster increases, the unit cost of buttons decreases because the firms generate sufficient demand to realize scale economies in button production and can support a wider variety of buttons.

firm (point *a*) to \$0.25 for a six-firm cluster (point *f*). The lower cost provides an incentive for dressmakers to cluster to share a buttonmaker.

High-Technology Firms

The lessons from the button–dressmaker story apply to other industries. Firms producing high-technology products face rapidly changing demand for their cutting-edge products. The small, innovative firms share the suppliers of intermediate inputs, such as electronic components, and cluster to get the face time required to match components and new products. Innovative high-technology firms also share firms that provide product-testing services and locate close enough to quickly tap the facilities.

Intermediate Inputs in the Movie Industry

The U.S. movie industry is concentrated in the area in and around Hollywood, CA. There are seven major studios and hundreds of independent movie producers. Both types of movie producers rely on other firms to provide all sorts of intermediate inputs, such as script writing, film processing and editing, orchestras, and set design and construction. The scale economies associated with producing these inputs are large relative to the demands of individual firms, so movie producers share the suppliers of intermediate inputs. The inputs are not standardized and require face-to-face collaboration in their design and production. The result is a cluster of movie producers and the suppliers of intermediate inputs.

The market for movie props provides an example of intermediate inputs. The objects used in film scenes include mundane items such as table lamps and chairs, special items such as castoff medical instruments and vintage cars, and signature props such as elf ear tips and Gryffindor scarves. Although the major studios have their own internal props departments, most independent producers get their props from firms known as "prop houses." In the Hollywood area, there are three clusters of prop houses. Set decorators and dressers go from one prop house to another looking for the perfect object for the set, and the prop houses cluster to facilitate this comparison shopping.

SELF-REINFORCING EFFECTS CAUSE INDUSTRY CLUSTERS

So far we have seen that clustering is beneficial because it allows firms to take advantage of agglomeration economies from input sharing. What about the costs? In this part of the chapter, we will use an example of the clustering of movie producers to explore the costs and benefits of clustering. When agglomeration economies are strong enough to offset the cost of clustering, firms will form industry clusters, causing the development of specialized cities.

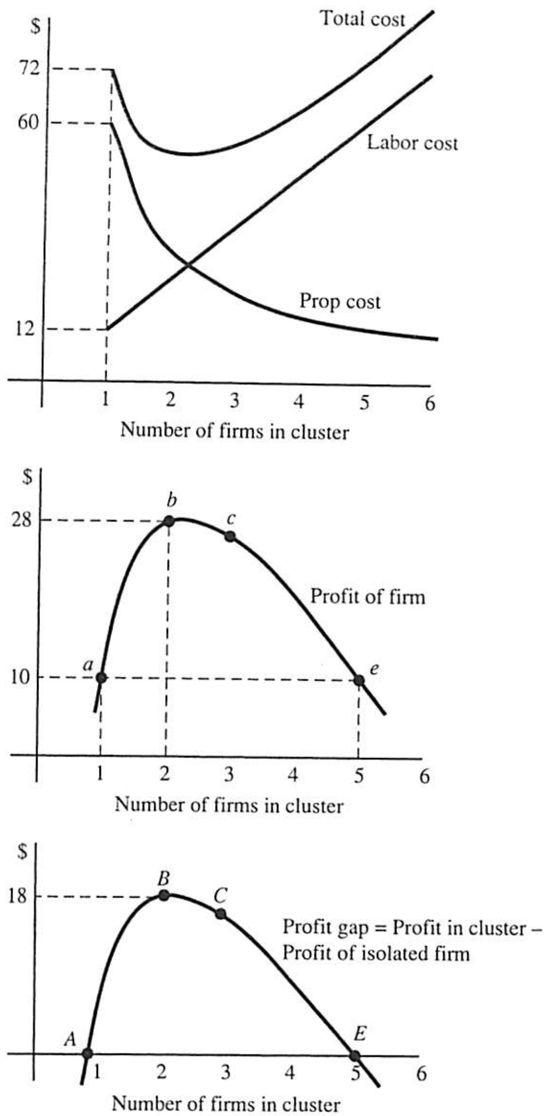
The Benefits and Costs of Clustering

Consider the location decisions of movie producers. Suppose the scale economies in providing movie props are large relative to the demand of an individual producer. As a result, movie producers won't run their own prop departments, but will instead purchase this intermediate input from prop houses. Locating in a cluster allows the producers to share prop houses and benefit from a lower price for props.

Figure 3–2 shows the trade-offs associated with clustering. In the upper panel, the negatively sloped curve shows the prop cost of the typical movie producer, which decreases as the number of producers in the movie cluster increases and the average cost—and price—of props decreases. The positively sloped curve shows the labor cost of the typical movie producer. The larger the number of firms in the cluster, the greater the competition for labor, and thus the higher the wages of movie workers and the higher the labor costs. The U-shaped curve shows the firm's total cost, equal to the sum of prop and labor costs. Going from one to two firms, the savings in prop cost dominate the increase in labor cost, and the total-cost curve reaches its minimum with two movie producers. Beyond that point, the increase in labor cost dominates, generating a positively sloped total-cost curve.

The middle panel of Figure 3–2 shows the profit of a typical movie producer for different numbers of producers in the cluster. Assume that the revenue of the typical producer is constant at \$82, and the profit equals this fixed revenue minus prop costs and labor costs. The profit of an isolated producer (a one-firm cluster), shown by point *a*, is \$10 = \$82 in revenue minus \$60 in prop cost and \$12 in

FIGURE 3–2 Self-Reinforcing Effects and Clustering



The profit gap, equal to the profit for firm in a cluster, minus the profit of an isolated firm increases, then decreases, reflecting the trade-offs from lower prop costs and higher labor costs. The profit gap reaches zero with five firms in the cluster, the equilibrium number.

labor cost. As the number of firms in the cluster increases, profit increases, then decreases. The inverted U reflects decreasing, then increasing total cost. With five producers in the cluster, the profit per producer again equals the profit of the isolated producer (point *e*).

The Profit Gap and the Size of the Cluster

The lower panel of Figure 3–2 shows the gap between the profit of a movie producer in a cluster and the profit of an isolated producer ($10). The profit gap is of course zero with a one-firm cluster (point *A*). The profit gap grows to $18 (point *B*, with 2 firms), then shrinks. In a five-firm cluster, the profit gap is again zero (point *E*).

How many movie producers will locate in the cluster? Suppose we have a large number of movie producers, and intially each is isolated, earning a profit of $10 (point *a* in the middle panel of Figure 3–2). Will this dispersed outcome persist? Suppose a single movie producer relocates next to another, forming a two-firm cluster. As shown in Figure 3–2, each firm in the cluster will earn $28 (point *b*), or $18 more than an isolated firm (point *B*). This higher profit gives the remaining isolated firms an incentive to relocate to the cluster. The third firm in the cluster will earn $26 in the cluster compared to $10 in isolation—a $16 gap (point *C*). Firms will continue to join the cluster as long as the profit gap is positive, that is, as long as the cluster location is more profitable than the isolated location. In the stable equilibrium, there are five firms in the cluster (point *E*). At this point, each firm in the cluster earns $10, the same as an isolated firm.

The agglomeration economies from sharing an intermediate input supplier generate self-reinforcing changes. Recall the second axiom of urban economics:

Self-reinforcing changes generate extreme outcomes

In this case, movie producers that compete for labor don't disperse to minimize labor costs, but instead cluster to realize agglomeration economies. In this example, rising labor costs generate diseconomies of scale that limit clustering, but the same logic applies with other diseconomies, such as rising land costs or rising transport costs for inputs and outputs.

SHARING A LABOR POOL

What do the producers of television programs and the producers of computer software have in common? Every year, dozens of new television programs are aired, and only a few are hits. In the rapidly changing software industry, hundreds of new products are introduced every year, and only a few succeed. For an individual firm in either industry, this year's new product—television program or computer program—may be wildly successful, and next year's may be a dud. In this environment of rapidly changing demand, unsuccessful firms will be firing workers at the same time that successful firms are hiring them. A cluster of firms facilitates the transfer of workers from unsuccessful firms to successful ones.

The key notion of sharing a labor pool is that the boom-bust process occurs at the level of the firm, not the industry. Suppose the total demand for output in an industry is constant over time, but the demand facing an individual firm varies from year to year. For example, the number of slots for television programs is fixed, so the success of one television firm (a hit) comes at the expense of another (a canceled dud). Similarly, the success of one firm's encryption software comes at the expense of other firms that introduce similar products.

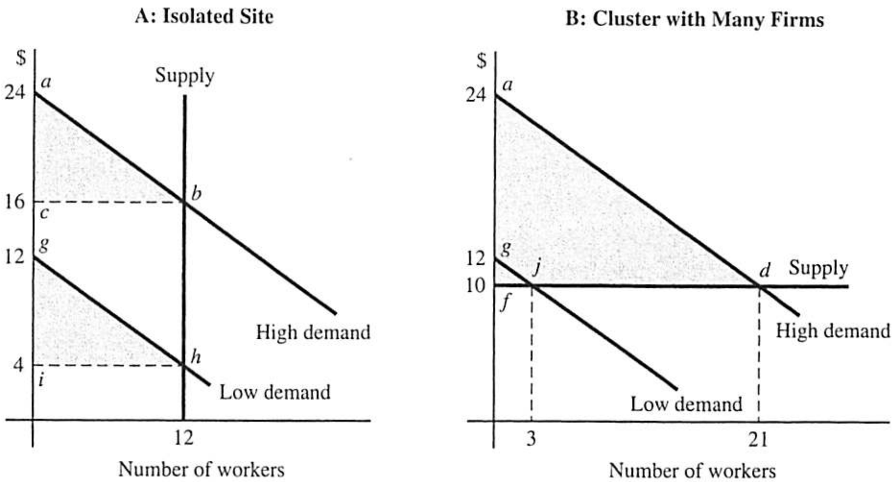
In this part of the chapter, we develop a formal model of labor pooling. The total demand at the industry level is constant, but the demand for each firm varies from year to year. For each firm, there are two possibilities—high demand or low demand—and each outcome is equally likely. As we'll see, there is an incentive for firms in such an industry to cluster to share a pool of workers.

The Isolated Firm

Consider first the situation for an isolated firm outside any industry cluster. The isolated firm doesn't face any competition for labor within its town, and to simplify matters, we assume that labor supply in the isolated site is perfectly inelastic, fixed at 12 workers. This means that wages will rise and fall with the demand for the firm's product.

When the demand for the firm's product is high, so is the firm's demand for labor. In Panel A of Figure 3–3, the high-demand equilibrium is shown by the intersection of the upper demand curve and the vertical supply curve at point *b*, generating a wage of $16. When demand for the firm's product is low, so is its demand for labor and the equilibrium wage ($4 at point *h*). To summarize, the isolated firm hires the same number of workers during high and low demand but pays a lower wage when demand is low.

FIGURE 3–3 Clustering to Share a Labor Pool



In an isolated site, the firm faces a perfectly inelastic supply of labor (12 workers). The firm hires the same number of workers during high demand and low demand but pays a higher wage during high demand.

In a cluster, the firm faces a perfectly elastic supply of labor, and the wage is fixed at $10. The firm hires 21 workers during high demand but only three workers during low demand.

Locating in a Cluster

The key difference between an isolated site and a cluster concerns the competition for labor and the variability of wages. Workers in the cluster can choose from a large number of firms. For every successful firm hiring workers, there is an unsuccessful firm firing them. Therefore, the total demand for labor in the cluster is constant, and so is the equilibrium wage.

Workers are mobile between the isolated site and the cluster, and in equilibrium they will be indifferent between the two locations. Recall the first axiom of urban economics:

Prices adjust to generate locational equilibrium

At the isolated site, the wage is uncertain, being either \$16 during high demand or \$4 during low demand. The two outcomes are equally likely, so the expected wage (the sum of the probabilities times the wages) is \$10:

$$\text{Expected wage} = \frac{1}{2} \cdot \$16 + \frac{1}{2} \cdot \$4 = \$10$$

To make workers indifferent between the two sites, the certain (constant) wage in the cluster must be \$10.

Panel B in Figure 3–3 shows the outcomes in the cluster. An individual firm can hire as many workers as it wants at the market wage. The typical firm hires 21 workers when demand is high (point *d*), but only three workers when demand is low (point *j*). When the demand for a firm's product goes from high to low, the firm fires 18 workers at the same time that another firm in the cluster is hiring 18 workers as its demand goes from low to high.

Expected Profits Are Higher in the Cluster

Expected profits will be higher in the cluster. To see why, consider what happens when a firm moves from the isolated site to a cluster and then experiences one year of high demand, followed by one year of low demand.

- **Good news when demand is high.** The move to the cluster cuts the wage (from \$16 to \$10) and allows the firm to hire more workers (21 instead of 12), generating higher profit in the cluster.
- **Bad news when demand is low.** The move to the cluster increases the wage (from \$4 to \$10), generating lower profit in the cluster.

Which is larger, the good news with high demand, or the bad news with low demand?

The good news will dominate the bad news because a firm in the cluster responds to changes in the demand for its product. When demand is high, the firm takes advantage of the lower wages (a \$6 gap) in the cluster by hiring more workers (21). When demand is low, a firm in the cluster cushions the blow of low demand by hiring fewer workers (only three). Because the firm changes its workforce when the demand for its product changes, the good news will be large relative to the bad news, and profit will be higher in the cluster.

Another way to show that profit is higher in the cluster is to compute the expected profits at the two sites. As shown in Section 3 of "Tools of Microeconomics" (the Appendix to the book), the labor-demand curve shows the marginal benefit of labor, the value of output produced by the marginal worker. A firm's profit from hiring a worker equals the difference between the worker's marginal benefit and the wage, and a firm's profit from its entire workforce is shown by the gap between the labor demand curve and the horizontal wage line. In Panel A of Figure 3–3, triangle *abc* shows the profit for an isolated firm when demand is high ($48), and triangle *ghi* shows the profit when demand is low ($48). In Panel B, the profit with high demand is shown by triangle *adf* ($147), and the profit with low demand is shown by triangle *gjf* ($3). So if the two outcomes are equally likely, the expected profit in the cluster is $75 (the average of $147 and $3), compared to $48 in the isolated site.

Labor Pooling in the Movie Industry

The U.S. movie industry, concentrated in the area in and around Hollywood, CA, provides an example of the benefits of labor pooling. One segment of the labor market includes workers involved in the craft and technical side of the industry. These workers move periodically from one producer to another as projects come and go, and rely on an "economy of favors," building and maintaining personal relationships to keep informed about potential jobs and ease the moves from one firm to another. The same phenomenon occurs for creative workers (actors, directors, writers) as they move between firms to work on different projects. In a cluster of movie producers, firms draw from a common labor pool, facilitating the flow of workers between firms.

There are a number of mechanisms that facilitate coordination in the local labor market and improve the flow of workers between firms. Intermediaries such as agents, casting directors, and talent managers match labor demanders and suppliers. Dozens of worker associations, including the Production Assistants Association and the Stuntmen's Association, provide useful information and training programs to their members. Colleges and universities in the area have professional programs that train students in the production of film and television. These coordinating mechanisms improve the efficiency of the labor market and help maintain the competitive advantages of the movie-industry cluster.

LABOR MATCHING

In a typical economic model of a labor market, we assume that workers and firms are matched perfectly. Each firm can hire workers who have precisely the skills the firm requires. In the real world, things are not so tidy. Workers and firms are not always perfectly matched, and mismatches require costly worker training. As we'll see, a large city can improve the matching of workers and firms in the untidy real world, decreasing training costs and increasing productivity.

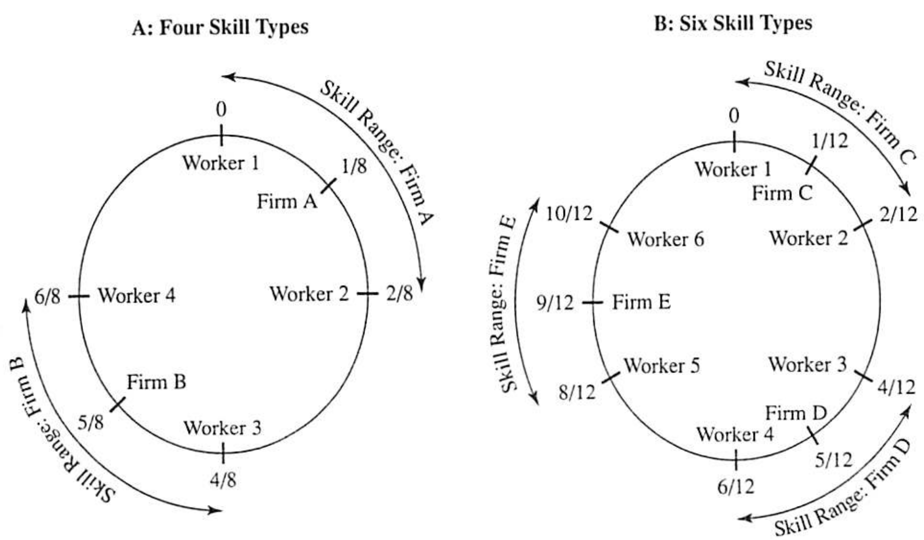
As an illustration of the labor matching problem, consider a set of software firms that hire computer programmers. Programmers have different skill sets, depending on their facility with different programming languages (e.g., C, C++, Java) and their experience with different programming tasks (e.g., graphics, number crunching, artificial intelligence, operating systems, e-commerce). Although some programmers are more productive than others, what matters for the matching model is that they have different skill sets. A firm enters the market with a particular skill requirement and hires workers who provide the best skill matches.

A Model of Labor Matching

Helsley and Strange (1990) developed a formal model of labor matching. The model uses several key assumptions about workers and firms.

- **Variation in worker skills.** Each worker has a unique skill described by a position or "address" on a circle with a one-unit circumference. In Panel A of Figure 3–4, there are four workers, and their skills are evenly spaced on the circle. The address of a worker is the distance between her skill position and the north pole of the circle. The addresses of the four workers are {0, 2/8, 4/8, 6/8}.

FIGURE 3–4 Skills Matching



With four skill types, worker addresses are {0, 2/8, 4/8, 6/8}. There are two workers per firm, so two firms will enter with skill requirements {1/8, 5/8}, and the mismatch per worker is 1/8.

With six skill types, worker addresses are {0, 2/12, 4/12, 6/12, 8/12, 10/12}. There are two workers per firm, so three firms will enter the market with skill requirements {1/12, 5/12, 9/12}, and the mismatch per worker is 1/12.

- **Firm entry.** Each firm enters the market by picking a product to produce and an associated skill requirement. In Panel A of Figure 3–4, one firm enters with skill requirement $S = 1/8$, and a second enters with $S = 5/8$.
- **Training costs.** Workers incur the cost associated with closing the gap between the worker's skill and the skills required by a firm.
- **Competition for workers.** Each firm offers a wage payable to any worker who meets its skill requirement, and each worker accepts the offer with the highest net wage, which is equal to the wage minus the training cost required to close the skills gap.

The next two assumptions of the matching model are related to the axioms of urban economics:

Production is subject to economies of scale

Because of scale economies in production, each firm will hire more than one worker. This is important because in the absence of scale economies, each firm would hire just one worker, and each worker would be perfectly matched with a firm. To simplify matters, we will assume that scale economies require each firm to hire two workers. The final assumption is that entry is unrestricted, so firms will continue to enter the market until economic profit is zero.

Competition generates zero economic profit

In the labor-matching model, entry involves picking a skill requirement and hiring workers with closely matched skills. In other words, each firm gets a local monopsony (single buyer) in the skill interval surrounding its skill requirement.

Panel A of Figure 3–4 shows the equilibrium with four skill types and two firms. The equilibrium mismatch per worker is 1/8. For example, the workers at $S = 0$ and $S = 2/8$ work in a firm with $S = 1/8$, so each worker has a skills gap of 1/8. Each firm pays a gross wage equal to the value of output produced by a perfectly matched worker. The net wage earned by a worker equals the gross wage minus the training cost:

$$\text{Net wage} = \text{Gross wage} - \text{Skills gap} \cdot \text{Unit training cost}$$

Suppose the gross wage is \$12 and the unit training cost is \$24. In the equilibrium shown in Panel A of Figure 3–4, the skill gap is 1/8, so the net wage is

$$\text{Net wage} = \$12 - \frac{1}{8} \cdot \$24 = \$9$$

Agglomeration Economies: More Workers Implies Better Matches

What happens to skills matching as an urban economy grows? We can represent an increase in the size of the workforce by increasing the number of workers on the unit circle. This increases the density of workers with respect to skills but doesn't change the range of skills. As we'll see, more workers means better skill matches and higher net wages.

TABLE 3–2 Number of Workers, Skills Gap, and Net Wage

Number of Workers	Skills Gap	Training Cost	Net Wage
4	1/8	\$24/8 = \$3	\$12 – \$3 = \$9
6	1/12	\$24/12 = \$2	\$12 – \$2 = \$10
12	1/24	\$24/24 = \$1	\$12 – \$1 = \$11

Panel B of Figure 3–4 shows the effects of increasing the number of workers from four to six. Each firm still hires two workers, so three firms will enter the market. In Panel B of Figure 3–4, the six workers are equally spaced, with skill addresses {0, 2/12, 4/12, 6/12, 8/12, 10/12}. The three firms enter the market with skill requirements {1/12, 5/12, 9/12}, so the mismatch per worker drops to 1/12. For example, workers at skill addresses 0 and 2/12 are hired by the firm at address 1/12, so each worker has a mismatch of 1/12. Workers incur lower training cost, so the net wage increases to \$10:

$$\text{Net wage} = \$12 - \frac{1}{12}\$24 = \$10$$

In general, an increase in the number of workers decreases mismatches and training costs, increasing the net wage. This is shown in Table 3–2 for up to 12 workers.

What are the implications of skill matching for the clustering of firms and urban development? The presence of a large workforce attracts firms that compete for workers, generating better skill matches and higher net wages for workers. The higher net wage provides an incentive for workers to live in large numbers in cities, so the attraction between firms and workers is mutual. Both firms and workers benefit from better skill matching.

KNOWLEDGE SPILLOVERS

A fourth agglomeration economy comes from sharing knowledge among firms in an industry. As Marshall (1920) explained,

> When an industry has chosen a locality for itself, it is likely to stay there for long; so great are the advantages which people following the same skilled trade get from near neighborhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is appreciated; inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed; if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of new ideas.

There is ample evidence that knowledge spillovers cause firm clustering. Dumais, Ellison, and Glaeser (2002) show that knowledge spillovers increase the number of new plant births, with the largest effect on industries that employ college graduates. Their results suggest that knowledge spillovers are important in determining the locations of firms in idea-oriented industries. Rosenthal and Strange (2001) show that the most innovative industries are more likely to form clusters. They also show that knowledge spillovers are highly localized, petering out over a distance of a few miles.

There is also evidence that knowledge spillovers are more important for industries with small, competitive firms. A recent study compared two clusters of the electronics industry, California's Silicon Valley and Route 128 near Boston (Saxenian, 1994). Knowledge spillovers are more important in Silicon Valley because its network of specialized companies generates an atmosphere of collaboration, experimentation, and shared knowledge. In contrast, the firms in the Route-128 cluster are less interdependent so there are fewer knowledge spillovers.

EVIDENCE OF LOCALIZATION ECONOMIES

A large volume of economics literature examines the magnitude of localization economies. In searching for evidence of localization economies, researchers focus on the effects of industry concentration on (1) worker productivity, (2) the number of new production plants (plant births), and (3) growth in industry employment. If there are localization economies, we expect industry clusters to generate higher productivity, more births, and more rapid employment growth.

Consider first the effect of concentration on worker productivity. Henderson (1986) estimates the elasticity of output per worker with respect to industry output, defined as the percentage change in output per worker divided by the percentage change in industry output. For the electrical machinery industry, the elasticity is 0.05, meaning that a 10 percent increase in the output of the industry increases output per worker by 0.50 percent. The elasticity estimates for other U.S. industries range from 0.02 for the pulp and paper industry to 0.11 for the petroleum industry.

Mun and Hutchison (1995) use data from Toronto to estimate agglomeration economies in the office sector. They estimate a productivity elasticity of 0.27, suggesting that localization economies are more powerful in the office sector than in the manufacturing sector. The productivity effects are larger for growth in central locations and are localized.

Consider next the implications of industry concentrations for the location of new production facilities. Carlton (1983) examines the location choices of firms in three industries: plastics products, electronic transmitting equipment, and electronic components. His estimated elasticity of firm births with respect to industry output is 0.43: A 10 percent increase in industry output increases the number of births by 4.3 percent. More recently, Head, Reis, and Swenson (1995) show that Japanese corporations locate their new plants close to other Japanese plants in the same industry. Rosenthal and Strange (2003) show that firm births are more numerous in locations close to concentrations of employment in the same industry.

Consider next the effects of industry concentration on employment growth. Henderson, Kuncoro, and Turner (1995) show that growth in mature industries is more rapid in areas that start with large concentrations of the industry. Rosenthal and Strange (2003) compute this localization effect for six industries, including computer software. A zip code area that starts out with 1,000 more software jobs than another zip code area experiences a larger increase in software employment—about 12 more jobs. On average, the localization effect peters out at a rate of about 50 percent per mile. The rapid attenuation of the localization economies explains the local in "localization economies."

URBANIZATION ECONOMIES

So far in this chapter, we have considered agglomeration economies experienced within a particular industry, also known as localization economies. These localization economies generate clusters of firms producing the same product. In contrast, urbanization economies—defined as agglomeration economies that cross industry boundaries—cause firms of different industries to locate close to one another. The result is the development of large, diverse cities. The four agglomeration economies that generate localization economies also generate urbanization economies.

Sharing, Pooling, and Matching

Consider first the notion of input sharing. Although some intermediate inputs such as buttons are specific to an industry, others are shared by firms in different industries. For example, most industries use business services such as banking, accounting, building maintenance, and insurance. Similarly, firms in different industries share hotels and firms providing transportation services. In addition, firms share public infrastructure such as highways, transit systems, ports, and universities. By sharing these intermediate inputs, firms in larger cities pay lower prices and tap a wider variety of inputs.

Another source of agglomeration economies is labor pooling. Recall that labor pooling is beneficial when the product and labor demand per firm varies while total industry demand remains constant. A cluster of firms in the same industry facilitates the movement of workers from firing firms to hiring firms. Labor pooling generates urbanization economies when demand varies across industries, with some industries expanding while others decline.

Consider next the benefits of labor matching. Recall that an increase in a city's workforce increases the density of worker skills, reducing the mismatches between workers' skills and firms' skill requirements. Because some skill requirements are common to multiple industries, the benefits of labor matching cross industry boundaries. For example, firms in many industries require computer programmers, and firms in these industries benefit from producing in a city with a high density of programmers.

Corporate Headquarters and Functional Specialization

Corporations locate their headquarters in cities to exploit urbanization economies. Corporate executives and managers perform a variety of tasks—developing marketing campaigns, picking locations for new plants, and fending off lawsuits—and draw on other firms to accomplish these tasks. Corporate expenditures on outsourced legal, accounting, and advertising services are equivalent to about two-thirds of their wage bill (Aarland, Davis, Henderson, Ono, 2003).

TABLE 3–3 Increase in Functional Specialization of Metropolitan Areas

	Percentage Gap between Metropolitan Ratio of Management to Production Workers and the National Ratio		
Population	1950	1970	1990
5–20 million	+10.2	+22.1	+39.0
1.5 to 5 million	+0.30	+11.0	+25.7
75,000 to 250,000	−2.1	−7.9	−20.7
67,000 to 75,000	−4.0	−31.7	−49.5

Source: Gilles Duranton and Diego Puga. "From Sectoral to Functional Specialization," *Journal of Urban Economics* 57 (2005), pp. 343–70.

Corporations cluster to share firms that provide business services. For example, given the large economies of scale in producing advertising campaigns, corporations cluster to share advertising firms, and they get specialized marketing campaigns at a lower cost. Similarly, corporations are attracted by the large concentrations of firms providing financial and business services in midtown Manhattan, the Loop in Chicago, and the financial district of San Francisco.

In the last several decades, there has been a fundamental shift in the specialization of cities. Large cities have become increasingly specialized in managerial functions, while smaller cities have become more specialized in production. Duranton and Puga (2005) compute the ratio of managerial workers to production workers for the nation as a whole and for different metropolitan areas. Table 3–3 shows the percentage differences between the national ratio and the metropolitan ratio for metropolitan areas of different sizes. For example, in the largest metropolitan areas in 1950, the metropolitan ratio was 10.2 percent higher than the national ratio, indicating a slight specialization in managerial functions. At the other extreme, for the smallest areas, the metropolitan ratio was 4.0 percent lower than the national ratio, indicating slight specialization in production.

Over the 40-year period shown in Table 3–3, there was a dramatic change in specialization. By 1990, the ratio for largest cities was 39 percent higher than the national ratio, indicating substantial specialization in managerial functions. At the other extreme, the ratio for the smallest cities was nearly 50 percent lower than the national ratio, indicating a high degree of specialization in production. These changes in specialization were caused by decreases in the cost of managing production facilities from afar. Firms are better equipped to operate multiplant firms from headquarters in large cities where agglomeration economies generate lower production costs. The most important cost reductions have come from innovations in telecommunications, in particular the development of duplicators (photocopiers, fax machines, and e-mail) that have facilitated the rapid transmission of information and reduced the cost of coordination.

Knowledge Spillovers

The essential feature of knowledge spillovers is that physical proximity facilitates the exchange of knowledge between people, leading to new ideas. The ideas lead to new products as well as new ways to produce old products. Some knowledge spillovers occur within an industry, but knowledge spillovers often cross industry boundaries. A city that produces a wide variety of products is fertile ground for applying ideas refined in the design and production of one product to new products.

Carlino and Hunt (2009) study the factors that determine the incidence of patents across metropolitan areas. After adjusting the raw number of patents to incorporate their relative importance (reflected in the number of times a patent is cited in other patents), they computed the elasticities of patent intensity with respect to a number of variables, including the following.

- **Employment density (jobs per square mile).** The overall elasticity is 0.22: a 10 percent increase in employment density increases patent intensity by about 2.22 percent. There are diminishing returns to density: the positive relationship levels off at an employment density of about 2,200 jobs per square mile.
- **Total employment.** The overall elasticity is 0.52: a 10 percent increase in total employment increases patent intensity by about 5.2 percent. There are diminishing returns to total employment: the positive relationship levels off at a metropolitan population of about 1.8 million.
- **Human capital (share of workforce with a college degree).** The elasticity is 1.05: A 10 percent increase in the share of the population with a college degree increases patent intensity by 10.5 percent.
- **Establishment size.** The elasticity is −1.4: a 10 percent increase in the average size decreases patent intensity by 14 percent. It appears that people in cities with relatively competitive environments are more inventive.

The authors also document the substantial variation in patent intensity across metropolitan areas. The average patent intensity is 2.0, and the values ranging from 0.07 (in McAllen, TX) to 17 (in San Jose, CA). Following San Jose in the rankings are Rochester, NY; Trenton, NJ; Ann Arbor, MI; Austin, TX; Wilmington, DE; Raleigh-Durham, NC; Boston, MA; and San Francisco, CA.

Evidence of Urbanization Economies

There have been many studies of urbanization economies. The general conclusion is that the elasticity of productivity with respect to population is in the range 0.03 to 0.08 (Rosenthal and Strange, 2004). In other words, a doubling of population increases output per worker by between 3 percent and 8 percent. Two studies (Glaeser, Kallal, Scheinkman, and Schleifer, 1992, and Henderson, Kuncoro, and Turner, 1995) suggest that diversity promotes employment growth, especially in new and innovative industries. Hanson (2001) concludes that long-run industry growth is higher in cities with a wider variety of industries, suggesting that diversity promotes growth.

OTHER BENEFITS OF URBAN SIZE

The urbanization economies discussed so far—input sharing, labor pooling, skills matching, and knowledge spillovers—generate higher productivity and lower production costs. In this part of the chapter, we'll consider three other advantages associated with a larger urban economy: better employment opportunities for families, a better learning environment for workers, and better social opportunities.

These advantages of size increase the relative attractiveness of large cities and increase the supply of labor to big cities. How does that contribute to the clustering of firms in cities? Recall the first axiom of urban economics:

Prices adjust to generate locational equilibrium

An increase in the relative attractiveness of a big city decreases the wage that workers are willing to accept to live and work in the city, generating lower production costs for firms. This is similar to the Dullsville versus Coolsville example in Chapter 1: A city that has superior opportunities for family employment, learning, and social interactions has lower wages, everything else being equal.

Joint Labor Supply

Most families have two workers, but are tied to a single residential location. In other words, families must confront the problem of joint labor supply. If the skills of the two workers are suited to different industries, the family will be attracted to locations with a mix of industries. Therefore, the joint supply of labor encourages firms in different industries to cluster. The role of cities in resolving the issue of joint labor supply has a long history. In the 1800s, mining and metal-processing firms (employing men) located close to textile firms (employing women), and each industry benefited from the presence of the other. More recently, "power couples" (defined as a pair of college graduates) are concentrated in large cities, where they are more likely to find good employment matches for both workers.

Learning Opportunities

Another benefit of urban size comes from the greater learning opportunities in cities. Human capital is defined as the knowledge and skills acquired by workers in formal education, work experience, and social interaction. Human capital can be increased through learning by imitation, that is, observing other workers and imitating the most productive workers. A larger city provides a wider variety of role models for workers so it attracts workers looking for learning opportunities.

The evidence for urban learning comes from data on the wages earned by workers who migrate to cities (Glaeser, 1999). Wages are higher in cities, reflecting the higher productivity of urban workers. But when a worker migrates from a rural area, she doesn't earn the higher urban wage immediately. Instead she experiences rising wages over time as learning increases her productivity. When a worker leaves the city, her wage does not drop back to the wage she earned prior to coming to the city. Instead, the higher productivity resulting from urban learning leads to a higher wage outside the city. In other words, the benefits of urban learning translate into higher wages everywhere.

Social Opportunities

A third benefit of city size comes from social interactions. An implicit assumption of the backyard-production model in Chapter 2 is that people do not value social interaction. Of course, people enjoy interacting with one another, and a larger city provides more opportunities for social interactions.

To think about the social dimension of cities, recall the labor-matching model. Suppose we replace labor skills with social interests: People have different hobbies, conversational topics, and social activities. In addition, suppose we replace firms seeking good skills matches with people seeking a network of friends with similar interests. In a model of social-interest matching, a larger city will generate better interest matches, with each network (like each firm) achieving a tighter range of social interests. Some people live in cities to take advantage of better opportunities for social-interest matching.

To illustrate the notion of social benefits of large cities, suppose you want to form a book club to discuss your favorite book, *Giles Goat Boy* (by John Barth). In a small town, you may be the only person who has read the book. In contrast, thousands of people in the typical large city have read the book and perhaps a dozen will be eager to discuss the masterpiece. A quick Internet search reveals that larger cities have more book clubs on a wider variety of topics, consistent with the notion that bigger cities provide better social matches.

SUMMARY

Firms cluster to exploit agglomeration economies, including localization economies at the industry level and urbanization economies at the city level. Here are the main points of the chapter:

1. Firms may cluster to share a supplier of an intermediate input if the input is subject to relatively large scale economies and requires face time for its design and production.
2. Firms may cluster to share a labor pool if the variation in product demand is greater at the firm level than at the industry level.
3. Larger cities provide better skill matches, leading to higher productivity and wages.
4. People and firms are attracted to cities because they facilitate knowledge spillovers, learning, and social opportunities.
5. Agglomeration economies cause self-reinforcing changes in location: The movement of one firm to a city increases the incentive for other firms to move to the city.

APPLYING THE CONCEPTS

For exercises that have blanks (________), fill each blank with a single word or number. For exercises with ellipses (...), complete the statement with as many words as necessary. For exercises with words in square brackets ([increase, decrease]), circle one of the words.

1. **Attention Kmart Shoppers**
Most of the dresses sold in the United States are produced in large factories that are dispersed, not concentrated. Reconcile this fact with the text discussion of localization economies that cause dressmakers to cluster.
2. **Labor Pooling: What's Fixed and Variable?**
Consider the model of labor pooling, with each firm locating either in an isolated site or in a cluster with other firms. Fill the blanks with "fixed" or "variable."
   - **a.** In an isolated site, the wage is ______ and the firm's workforce is ______ because. . . .
   - **b.** In a cluster, the wage is ______ and the firm's workforce is ______ because. . . .
   - **c.** Illustrate with two graphs, one for the isolated site and one for the cluster.
3. **Trade-offs with Clustering for Labor Pooling**
Consider the model of labor pooling, with each firm locating either in an isolated site or in a cluster with other firms. Suppose that good times (high demand) and bad times (low demand) are equally likely. The table shows wages and workforces in different times and locations.

	Isolated		Cluster	
	Wage	Workforce	Wage	Workforce
Good times (high demand)	$40	50	$30	60
Bad times (low demand)	$20	50	$30	40

   - **a.** Use a figure like Figure 3–2 to illustrate the situation.
   - **b.** During good times, the benefit of being in the cluster as opposed to being isolated is ______, computed as. . . .
   - **c.** During bad times, the cost of being in the cluster as opposed to being isolated is ______, computed as. . . .
   - **d.** The benefit exceeds the cost because a firm in a cluster. . . .
4. **Mr. Mullet's Carnival**
Mr. Mullet runs a traveling carnival that hires local workers in each city it visits. The demand for carnival activities is uncertain, with low or high demand equally likely in any given city. At the end of the year, Mr. Mullet reviews his financial records and discovers some puzzling differences between his experiences in small and large cities.
   - **i.** He always paid the same wage in large cities ($9), but paid different wages in small cities ($6 or $12).
   - **ii.** He always hired the same quantity of labor in small cities (20 workers), but different quantities in big cities (10 or 30 workers).
   - **a.** Using Figure 3–3 as a model, illustrate with two graphs, one for the typical small city and one for the typical big city. Assume that the demand curves

for labor are linear and parallel, with vertical intercepts of \$18 (high demand) and \$12 (low demand).

b. In the typical big city with high demand, profit is ______ computed as. . . .

c. In the typical big city with low demand, profit is ______ computed as. . . .

d. In the typical small city with high demand, profit is ______ computed as. . . .

e. In the typical small city with low demand, profit is ______ computed as. . . .

f. The expected profit is ______ in a big city, compared to ______ in a small city.

5. Number of Workers and Net Wages

Using Table 3–2 as a starting point, suppose the gross wage is \$36 and the unit training cost is \$48. Complete the following table.

Number of Workers	Skills Gap	Training Cost	Net Wage
4	______	______	______
8	______	______	______
24	______	______	______

6. Models on the Color Wheel

Consider the model-management industry, with firms that supply human models for advertisements. Workers (models) vary in skin tone along the color wheel, which can be divided into 12 colors. Firms enter the market with a specific skin tone requirement for their models. If a model's skin tone does not match the firm's tone requirement, the model incurs a makeup cost to close the gap, with a cost of \$3 for each unit of color shift. For example, to go from color #2 to color #4, the cost is \$6. Given the scale economies in model management, each firm manages three models. The gross wage is \$20.

a. Smallville has six models, equally spaced on the color wheel at 12:00, 2:00, 4:00, and so on. There will be ______ firms in the city, with firm A at 12:00 and the other firm or firms at ______.

b. Illustrate with a graph like Figure 3–4.

c. For the typical firm, the average mismatch is ______ skin tones and the average makeup cost is \$ ______. The average net wage after makeup costs is ______, computed as. . . .

d. Bigburg has twice as many models as Smallville. It will have ______ firms. Its average makeup costs will be [lower, higher] and its average net wage will be [higher, lower].

e. Complete the following table.

Number of Models	Color Gap	Makeup Cost	Net Wage
6	______	______	______
12	______	______	______

7. Advertising and Corporate Clusters

Consider corporations that use advertising firms to develop marketing campaigns. Each corporation buys one campaign per year, and the cost per campaign is \$120/n, where n = the number of corporations in the cluster (and campaigns per year). The cost of labor per firm is \$30 · n. A corporation's profit equals its total revenue of \$200 minus the sum of its marketing and labor costs. There are two location options: an isolated site ($n = 1$) or a cluster with up to five corporations.

a. Use a graph like Figure 3–2 to show the profit gap (profit in cluster – profit in isolation) for one through five corporations.

b. If initially all corporations are isolated and then one joins another to form a two-corporation cluster, other firms [will, won't] have an incentive to join the cluster because....

c. In the long-run equilibrium, there will be a cluster of ______ corporations, each of which will earn a profit of ______, differing from the profit of an isolated site by ______.

8. Agglomeration Economies and Auto Row

Chapter 1 uses Auto Row as an example of self-reinforcing changes that lead to extreme outcomes. Consider a city with three isolated automobile dealers, each of which has three buyers per day. The profit per car sold is \$1,000. A two-dealer cluster would get six times as many buyers (18), and a three-dealer cluster would get 12 times as many buyers (36).

a. Use a graph like Figure 3–2 to show the profit gap (the profit for a firm in a cluster minus the profit for an isolated firm) for one, two, and three dealers.

b. If initially all dealers are isolated and then one joins another to form a two-dealer cluster, other firms [will, won't] have an incentive to join the cluster because. . . .

9. Personal and Pet Grooming in the Minimall

Suppose that personal grooming and pet grooming are complementary products. Betty Beehive could move her beauty shop from an isolated location to a minimall that also contains Peter's pet-grooming shop. If she moves, she will attract some of Peter's customers and her pre-rent profit will increase by \$180. Her current rent is \$100, compared to \$300 in the minimall.

a. Betty [will, won't] make the move because....

b. Betty's presence in the minimall would increase Peter's profit by \$100. If you were the manager of the minimall, with the power to set the rent of each tenant, what would you do?

10. Diversify the Economy?

According to the conventional wisdom concerning urban economic development, a city should develop a diverse economy with a large number of industries. Evaluate the merits of this advice in light of the empirical evidence concerning the magnitudes of localization and urbanization economies.

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