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Chapter 9 General-Equilibrium Land Use

Everything should be explained as simply as possible, but not more so.
Albert Einstein

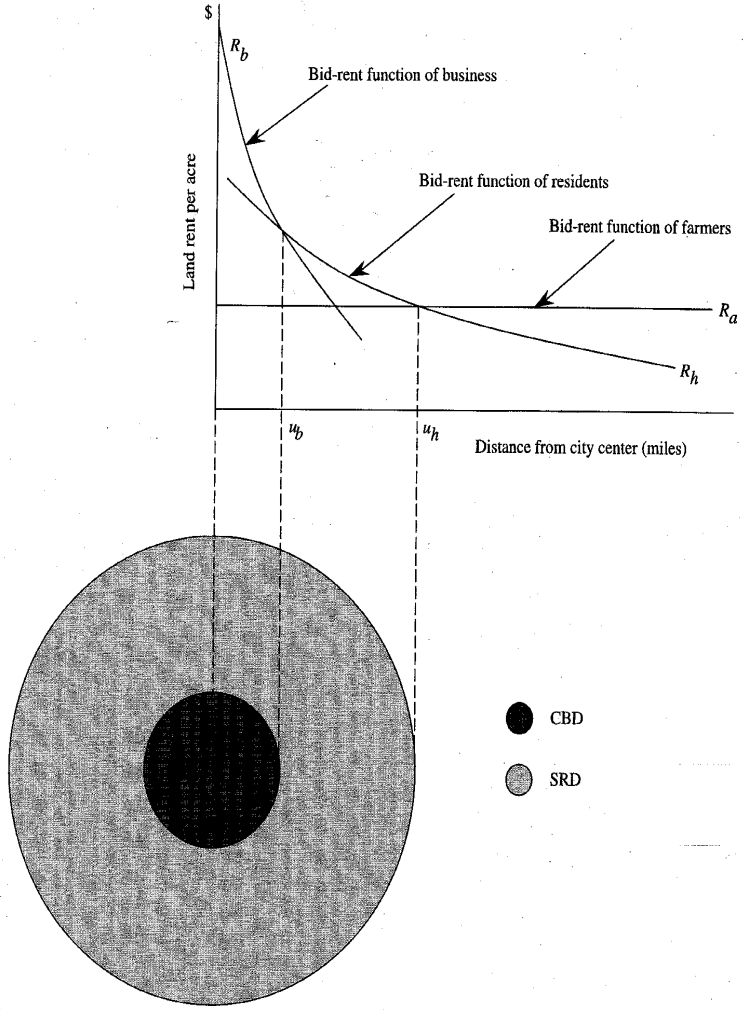
This chapter uses general-equilibrium analysis to explore the interactions between different parts of the urban economy. In contrast with partial-equilibrium analysis, which examines a single market in isolation, general-equilibrium analysis recognizes that markets are interdependent and explores the effects of changes in one market on related markets.

Urban general-equilibrium analysis explores the interactions between the residential land market, the business land market, and the urban labor market. It is used to predict the effects of changes in one part of the urban economy on land use throughout the urban area. This chapter uses general-equilibrium analysis to explore the effects of three changes in the monocentric city: an increase in export sales, the introduction of a streetcar system, and an increase in the residential property tax. Later in the book, general-equilibrium analysis is used to explore the land-use effects of changes in technology and public policy. Chapter 10 (Suburbanization and Modern Cities) explores the land-use effects of the truck and the automobile. Chapter 11 (Land-Use Controls and Zoning) examines the general-equilibrium effects of various land-use controls. Chapter 19 (Autos and Highways) explores the effects of highway congestion on land-use patterns.

General-Equilibrium Conditions

Figure 9–1 shows the equilibrium land-use pattern of a monocentric city. The bid-rent function of the business sector (office firms and manufacturers) is negatively sloped, reflecting the benefits of locating near the central market area and the central export node. The bid-rent function of residents is negatively sloped, reflecting the benefits of locating near jobs in office and manufacturing firms. The central business

FIGURE 9–1 Equilibrium Land-Use Pattern in a Monocentric City



Business firms outbid residents for central land, generating a CBD with radius u_b. The SRD is the area over which residents outbid firms and farmers, that is, a ring with width $(u_h - u_b)$.

district (CBD) is the area over which firms (office firms and manufacturers) outbid residents, so the radius of the CBD is u_b miles. The suburban residential district (SRD) is the area over which residents outbid firms and farmers, so the SRD is a ring of width $(u_h - u_b)$ miles. For land beyond u_h, farmers outbid residents, so the radius of the city is u_h miles.

The monocentric city is assumed to be one of hundreds of cities in a regional economy. The city is "open" in the sense that households and firms can costlessly enter or leave the city. The city is "small" in the sense that it is a trivial part of the regional economy, so that changes in the city do not affect the common utility level of the region's residents. Any change that increases the utility level of the city's residents causes in-migration from the rest of the region. This migration bids up the prices of housing and land (increasing the cost of living), decreasing the utility level of the city's residents. Migration continues until the original utility level is restored.

The urban economy achieves general equilibrium when four conditions are satisfied simultaneously:

1. **Locational equilibrium for firms.** If all firms make zero profits at all locations, there is no incentive to change locations. This condition is guaranteed by the business bid-rent function, R_b: competition for land bids up the price of land at locations with relatively low transportation costs, so firms are indifferent among all locations in the city.
2. **Locational equilibrium for households.** If all households achieve the same utility level at all locations in the city, there is no incentive to change locations. This condition is guaranteed by the residential bid-rent function, R_h: competition for land bids up the price of land at locations with relatively low commuting costs, so households are indifferent among all locations in the city.
3. **Competitive bidding.** Land is allocated to the highest bidder. This condition is satisfied if landowners, like other people in a competitive economy, seek the highest return on their assets.
4. **Labor-market equilibrium.** The total demand for labor (from office firms and manufacturers in the CBD) equals the total supply of labor (from residents in the SRD).

To summarize, general equilibrium occurs when both the land market and the labor market are in equilibrium at the same time.

Numerical Examples of General-Equilibrium Analysis

This section uses two numerical examples to explain the principles of general-equilibrium analysis. An increase in export sales has a direct effect on the CBD land market, and the introduction of a streetcar system has a direct effect on the SRD land market.

Initial Equilibrium

Table 9–1 shows the numbers associated with the monocentric city depicted in Figure 9–1. In initial equilibrium, the CBD radius is two miles, and the city radius is six miles. The land area of the CBD is computed with the formula for the area of a circle:

$$\text{CBD land area} = \pi \cdot (u_b)^2 \qquad (9\text{–}1)$$

TABLE 9–1 General-Equilibrium Effects of an Increase in Export Price and Export Sales

	Initial Equilibrium	*Partial Equilibrium*	*General Equilibrium*
Radius of CBD in miles (u_b)	2.0	2.5	2.2
Area of CBD (square miles)	12.56	19.63	15.20
Width of SRD in miles ($u_h - u_b$)	4.0	3.5	4.3
Area of SRD (square miles)	100.48	74.58	117.47
Radius of city in miles (u_h)	6.0	6.0	6.5
Area of city (square miles)	113.04	113.04	132.67
Wage ($ per hour)	10.0	10.0	13.0
Average labor density (workers per square mile)	20,000	22,000	21,000
Total labor demand (workers)	251,200	431,750	319,150
Average household density (households per square mile)	2,500	2,500	2,717
Total labor supply (workers)	251,200	186,438	319,150

Because u_b is 2 miles, the CBD land area is 12.56 square miles. The land area of the city is

$$\text{City land area} = \pi \cdot (u_h)^2 \qquad (9\text{–}2)$$

Because u_h is 6 miles, the land area of the city is 113.04 square miles. The land area of the residential district is the difference between the land areas of the city and the CBD, or 100.48 square miles.

The city is in general equilibrium because total labor supply equals total labor demand. Total labor demand equals the land area of the CBD times the average number of workers per square mile:

$$\text{Total demand} = \text{CBD land area} \cdot \text{Average employment density} \qquad (9\text{–}3)$$

In Table 9–1, the average employment density is 20,000 workers per square mile, so total labor demand is 251,200. Total labor supply equals the land area of the SRD times average household density (assuming that there is one worker per household):

$$\text{Total supply} = \text{SRD land area} \cdot \text{Average household density} \qquad (9\text{–}4)$$

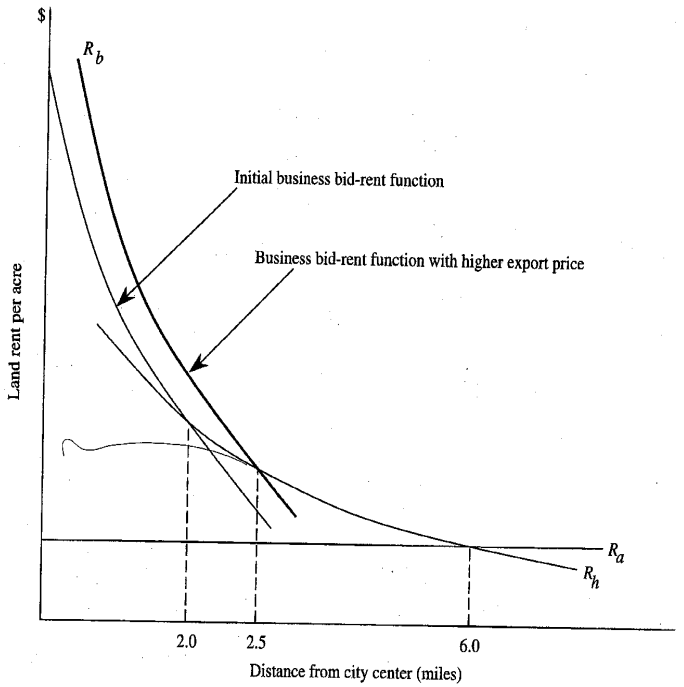
In Table 9–1, the average household density is 2,500 per square mile, so total labor supply is 251,200. Labor supply equals labor demand, so the land-use allocation shown in Figure 9–1 is an equilibrium allocation.

Increase in Export Sales

Suppose that the price of baseballs (the city's export good) increases. What are the effects of the price increase on the city's land and labor markets?

Consider first the effect of the price increase on the CBD land market. In the short run, the increase in price increases the profits of baseball firms. The demand for CBD land increases as (1) existing baseball firms increase their output and (2)

FIGURE 9–2 Partial-Equilibrium Effects of an Increase in Export Price and Export Sales



An increase in the price of exports shifts the business bid-rent function upward. The CBD expands (the radius increases from 2.0 miles to 2.5 miles) at the expense of the SRD (the width decreases from 4.0 miles to 3.5 miles).

new firms enter the baseball industry. The increase in the demand for land shifts the bid-rent function for business land upward, as shown in Figure 9–2. The upward shift of R_b is consistent with the leftover principle: at the higher baseball price, firms have a greater excess of revenue over nonland cost, so they are willing to pay more for land. As the business bid-rent function shifts upward, the CBD expands at the expense of the residential area: the radius of the business district increases from 2.0 miles to 2.5 miles, and the SRD shrinks from a width of 4.0 miles to 3.5 miles.

How does the upward shift of the business bid-rent function affect the urban labor market? Total labor demand increases for two reasons:

1. **CBD territory effect.** As shown in the second column of Table 9–1, the land area of the CBD increases from 12.56 square miles to 19.63 square miles.
2. **Employment density effect.** The increase in the relative price of land causes baseball firms to substitute nonland inputs (capital and labor) for land, increasing labor density (workers per square mile). In the second

column of Table 9–1, labor density has increased from 20,000 workers per square mile to 22,000.

In combination, these two effects increase total labor demand from 251,200 to 431,750. The upward shift of the business bid-rent function also decreases total labor supply: the CBD encroaches on SRD land, decreasing total supply from 251,200 to 186,438. Because labor demand increases and labor supply decreases, there is excess demand for labor.

The increase in price increases labor demand while it decreases labor supply, and the excess demand for labor increases the city's wage. The increase in the wage increases the quantity of labor supplied for two reasons:

1. **SRD territory effect.** An increase in the wage increases the relative attractiveness of the city. Laborers from the rest of the region move to the city, bidding up the prices of housing and residential land. R_h shifts upward, increasing the size of the SRD as residents outbid farmers (for land near the city border) and firms (for land near the CBD border). As the residential district expands, total labor supply increases.
2. **Household density effect.** As the price of housing increases, households substitute nonhousing goods for housing, so housing consumption per household decreases. In addition, as the price of residential land increases, housing producers substitute capital for land, so the amount of land per unit of housing decreases. In combination, these two changes decrease land consumption per household, that is, every household occupies a smaller lot. The decrease in land consumption increases household density (the number of households and laborers per square mile), increasing total labor supply.

To summarize, the increase in the wage increases the quantity of labor supplied because both the size and the density of the residential district increase.

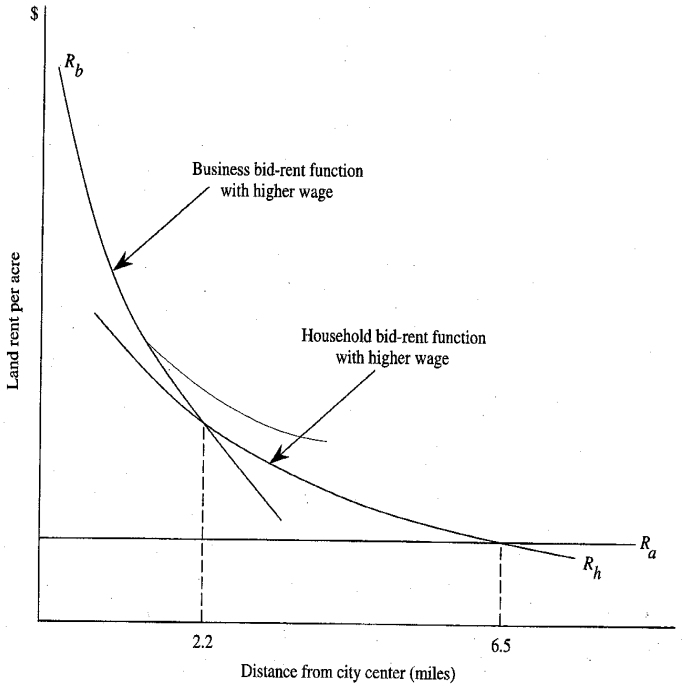
How does the increase in the wage affect the demand side of the labor market? The increase in the wage decreases the quantity of labor demanded for two reasons:

1. **CBD territory effect.** An increase in the wage increases production costs. Some firms decrease their output, and other firms shut down. The decrease in production activity decreases the demand for land, so the business bid-rent function drops. As the CBD loses territory to the residential district, total labor demand decreases.
2. **Employment density effect.** The increase in the wage decreases land rent. As the relative price of labor increases, firms substitute land for the relatively expensive labor. Labor density (the number of workers per square mile) decreases.

To summarize, the increase in the wage decreases the quantity of labor demanded because both the size and the density of the business district decrease.

These two changes in the labor market narrow the gap between labor supply and labor demand. The wage continues to rise until general equilibrium is restored. Figure 9–3 shows the new equilibrium allocation of land, and the third column of

FIGURE 9–3 General-Equilibrium Effects of an Increase in Export Price and Export Sales



The increase in the export price causes excess demand for labor, increasing the city's wage. The increase in the wage shifts the business bid-rent function downward and shifts the residential bid-rent function upward. The net effect is a larger CBD (the radius increases from 2.0 miles to 2.2 miles) and a larger SRD (the width increases from 4.0 miles to 4.3 miles).

Table 9–1 shows numbers behind the new allocation. The new equilibrium wage is $13 per hour (up from $10). The CBD radius is 2.2 miles, and labor density is 21,000 workers per square mile, so total labor demand is 319,150. The SRD is 4.3 miles wide and household density is 2,717 per square mile, so total labor supply is the same as total demand. In other words, general equilibrium is restored with a wage of $13. For a lower wage, labor demand would exceed supply; for a higher wage, supply would exceed demand.

There are four lessons from the general-equilibrium analysis of the increases in the export price:

1. **Market interactions.** Changes in the CBD (the business land market) affect the city's labor market and its residential land market. The upward shift of the business bid-rent function increases the size and the density of the CBD, causing excess demand for labor. The resulting increase in the wage shifts the bid-rent function of residents upward, increasing the size and density of the SRD.

2. **Shifts in bid-rent functions.** The increase in the export price causes an upward shift of the business bid-rent function (a partial-equilibrium effect). The resulting increase in the wage causes a downward shift of the business bid-rent function (a general-equilibrium effect).
3. **Land rent.** The increase in the export price increases land rent throughout the city. The increase in export production increases the demand for land in both the CBD and the residential district, so landowners throughout the city benefit from the increase in export sales.
4. **Welfare effects of increased export sales.** In general equilibrium, the city's residents are no better off in the larger city. The increase in the wage is offset by higher costs of housing and land, leaving the utility level unchanged. The increase in export sales increases the number of residents, not their utility.

A Streetcar System

As a second illustration of general-equilibrium analysis, suppose that the city installs a streetcar system. The streetcar decreases the time and monetary cost of commuting, causing a number of changes in the urban economy.

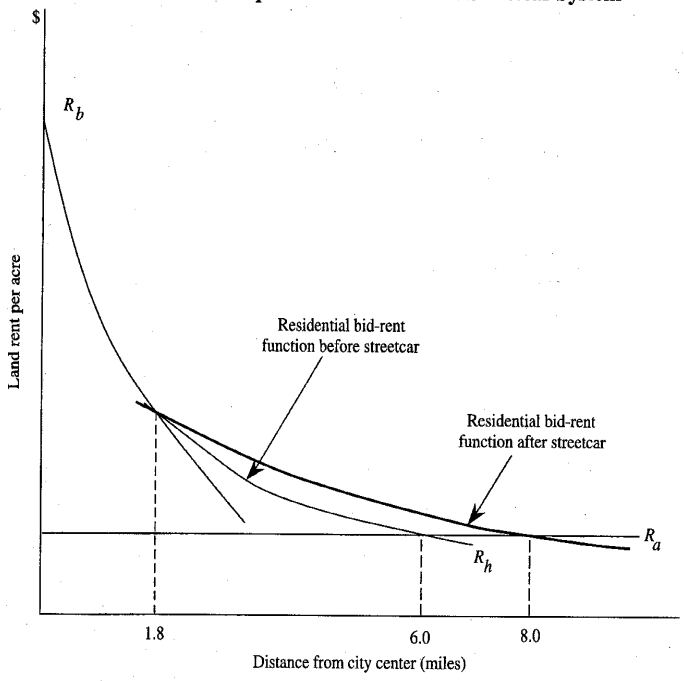
How does the streetcar system affect the residential bid-rent function? As explained in Chapter 8 (Land Use in the Monocentric City), the slope of the bid-rent function is determined by commuting costs: the lower the unit cost of commuting, the flatter the bid-rent function. In Figure 9–4, the streetcar system decreases the slope of the bid-rent function and increases the width of the SRD from 4 to 6.2 miles. The streetcar system makes peripheral areas accessible to CBD jobs, allowing residents to outbid farmers for land near the city's edge. In addition, residents outbid firms for the land near the CBD border. This is the partial-equilibrium effect of the streetcar system.

The upward tilt of the residential bid-rent function increases total labor supply for two reasons:

1. **SRD territory effect.** The expansion of the residential district increases labor supply. Table 9–2 shows an increase in the land area of the residential district from 100.48 square miles in column one to 190.88 square miles in column two.
2. **Household density effect.** The increases in the prices of housing and land cause consumer substitution (consumers substitute nonhousing goods for housing) and factor substitution (housing producers substitute nonland inputs for land). The lot size per household decreases, increasing population density. Table 9–2 shows an increase in household density from 2,500 in column one to 2,700 in column two.

To summarize, the streetcar system increases the quantity of labor supplied because it increases both the size and the density of the residential district. The streetcar system increases the relative attractiveness of the city, causing in-migration that bids up the price of land. People migrate from other cities because workers in the streetcar city

FIGURE 9–4 The Partial-Equilibrium Effect of the Streetcar System



The streetcar system decreases commuting cost, decreasing the slope of the residential bid-rent function. The width of the SRD increases from four miles to six miles, and the city radius increases from six miles to eight miles.

TABLE 9–2 General-Equilibrium Effects of a Streetcar System

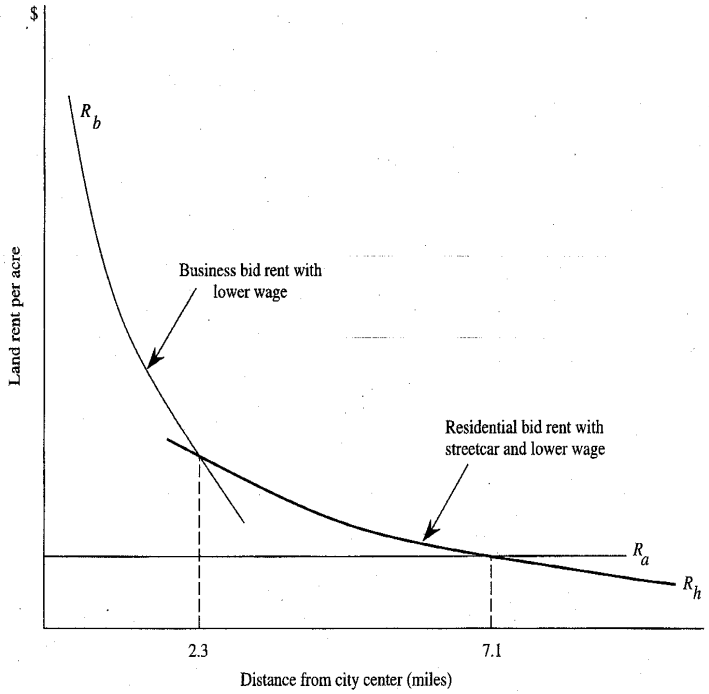
	Initial Equilibrium	*Partial Equilibrium*	*General Equilibrium*
Radius of CBD in miles (u_b)	2.0	1.8	2.3
Area of CBD (square miles)	12.56	10.18	16.61
Width of SRD in miles ($u_h - u_b$)	4.0	6.2	4.8
Area of SRD (square miles)	100.48	190.88	141.68
Radius of city in miles (u_h)	6.0	8.0	7.1
Area of city (square miles)	113.04	201.06	158.29
Wage ($ per hour)	10.0	10.0	6.0
Average labor density (workers per square mile)	20,000	20,000	22,000
Total labor demand (workers)	251,200	203,575	365,433
Average household density (households per square mile)	2,500	2,700	2,579
Total labor supply (workers)	251,200	515,380	365,433

have shorter commuting times, so they have higher net income (gross labor income less the time cost of commuting).

The streetcar causes an excess supply of labor. The CBD shrinks, so labor demand falls at the same time that labor supply increases. The excess supply of labor decreases the city's wage, causing changes on both sides of the labor market. On the demand side, the business bid-rent function shifts upward, increasing both the territory and the employment density of the CBD. On the supply side, the residential bid-rent function shifts downward, decreasing both the territory and density of the residential district.

These two changes in the labor market narrow the gap between labor supply and labor demand. The wage continues to drop until general equilibrium is restored. Figure 9–5 shows the new equilibrium allocation of land, and the third column of Table 9–2 shows numbers behind the new equilibrium. The new equilibrium wage is \$6 per hour (down from \$10). The CBD radius is 2.3 miles, and the SRD is 4.8 miles wide. The equilibrium number of laborers is 365,433. There are three basic lessons from the general-equilibrium analysis of the streetcar:

FIGURE 9–5 The General-Equilibrium Effect of the Streetcar



The streetcar causes excess supply of labor, decreasing the city's wage. The business bidrent function shifts upward, and the residential bid rent shifts downward. The CBD grows, and the SRD shrinks. General equilibrium is restored with a larger SRD (the width increases from 4.0 miles to 4.8 miles) and a larger city (the radius increases from 6.0 miles to 7.1 miles).

1. **Tilt and shift of the residential bid-rent function.** The streetcar affects the residential bid-rent function in two ways. The upward tilt (or flattening) of the function is the partial-equilibrium effect, which occurs because the streetcar decreases commuting cost. The downward shift is the general-equilibrium effect, which occurs because the streetcar causes an excess supply of labor, decreasing the city's wage.
2. **Land rent.** The streetcar increases land rent in both the SRD and the CBD. The streetcar increases the accessibility of residential land, so residents are willing to pay more for land. The streetcar also decreases wages and production costs, so firms are willing to pay more for land in the CBD. Landowners throughout the city benefit from the streetcar.
3. **Welfare effects of the streetcar.** In general equilibrium, the city's residents are no better off with the streetcar. Because the city is "open," the streetcar causes in-migration from the rest of the region that decreases wages and increases the prices of housing and land. The benefits of the streetcar (faster and cheaper commuting) are offset by lower wages and a higher cost of living.

The General-Equilibrium Effects of the Property Tax

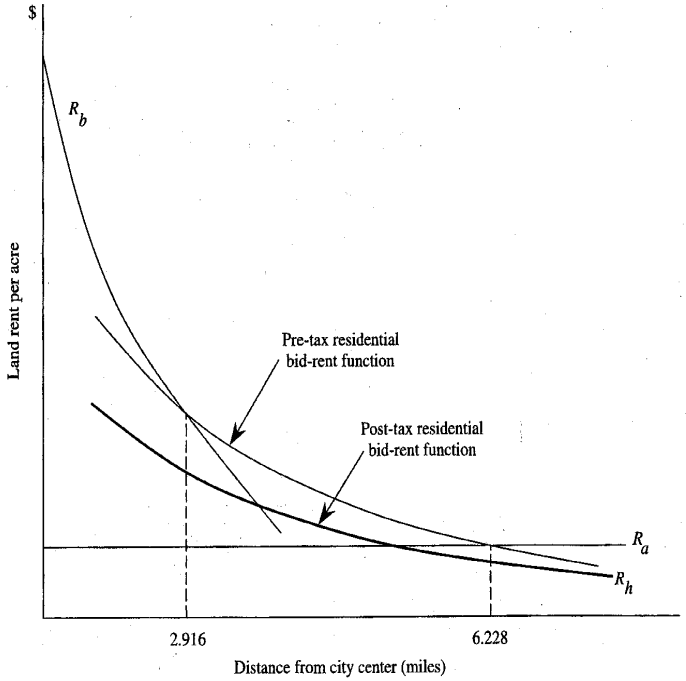
Consider a city that initially finances all of its public services with a land tax. If all the land in the city is owned by people living outside the city, the city's public services are initially financed by a tax on absentee landowners. Suppose that the city replaces its land tax with a tax on residential capital (improvements such as houses and apartments), and the capital tax is paid by the city's residents. Under the new tax policy, city residents pay more taxes but do not receive more public services.

How does the property tax affect the city's economy? There are two ways to answer this question. First, a graph can be used to show the partial-equilibrium effects of the tax. Second, a computer can be used to show the general-equilibrium effects of the tax.

Figure 9–6 shows the partial-equilibrium effects of the residential property tax. The property tax is a tax on both land and capital (improvements), so the tax liability increases with the amount of improvements. As explained in Chapter 8 (Land Use in the Monocentric City), the capital-land ratio increases as one approaches the city center because housing producers substitute capital for relatively expensive land. Because the amount of improvements per acre is larger closer to the city center, the tax liability per acre increases as one approaches the city center. For example, an apartment building on a one-acre site two miles from the city center faces a higher tax liability than a single-family home on a one-acre site five miles from the city center. Therefore, the closer the site to the city center, the larger the downward shift of the bid-rent function. This is shown in Figure 9–6: the gap between the pre-tax and post-tax bid-rent functions increases as one approaches the city center.

What are the general-equilibrium effects of the residential property tax? In other words, how does the tax affect the urban labor market? The downward shift of the residential bid-rent function decreases the territory and the density of the

FIGURE 9–6 Partial-Equilibrium Effects of the Residential Property Tax



The residential property tax is partly a tax on improvements, so it generates a larger tax burden on locations with large capital-land ratios. Therefore, the gap between the pre-tax and the post-tax residential bid-rent functions increases as one approaches the city center.

residential district, causing an excess demand for labor. The city's wage increases, causing changes in the CBD and SRD that narrow the gap between supply and demand. In the CBD, the increase in the wage increases production costs and decreases the bid rent for business land. The resulting decrease in the size and the density of the CBD decreases the quantity of labor demanded. In the SRD, the increase in the wage shifts the residential bid-rent function upward. The resulting increases in the size and the density of the residential district increase the quantity of labor supplied. The wage continues to fall until general equilibrium is restored.

What will the city look like after general equilibrium is restored? One way to answer this question is to use a computer to generate two pictures of the urban economy, one before the property tax is imposed and one after the economy has adjusted to the new tax. An urban general-equilibrium computer model allocates different plots of land in a hypothetical city to firms (labor demanders) and households (labor suppliers). If a particular allocation does not satisfy the conditions for general equilibrium, the computer tries a different allocation. This groping process continues until an equilibrium allocation is found. The computer model can be designed to compute a pre-tax equilibrium and a post-tax equilibrium. By comparing the "before" and

TABLE 9–3 General-Equilibrium Effects of the Residential Property Tax

	Initial Equilibrium	*General Equilibrium*
Number of households	250,038	255,853
Territories		
Radius of CBD (miles)	2.916	2.85
Width of SRD (miles)	3.582	3.378
Radius of city (miles)	6.498	6.228
Input Prices		
Wage ($ per hour)	10.00	10.02
Median CBD land rent ($ per acre per year)	28,999	26,016
Median SRD land rent ($ per acre per year)	2,886	2,761
Density		
Average labor density (workers per square mile)	9,360	8,851
Average household density (households per square mile)	2,359	2,344
Land Rent		
CBD land rent ($ per week)	7,053,134	6,258,973
SRD land rent ($ per week)	3,580,168	3,163,577
Total land rent ($ per week)	10,633,302	9,422,550

SOURCE: Arthur M. Sullivan, "The General Equilibrium Effects of the Residential Property Tax: Incidence and Excess Burden," *Journal of Urban Economics* 18 (1985), pp. 235–50.

"after" snapshots of the urban economy, one can identify the general-equilibrium effects of the property tax.

Sullivan (1985) used a computer model to simulate the effects of a 1.7 percent residential property tax. The results of the study are listed in Table 9–3. The hypothetical city has an initial work force of about 250,000 and a population of about 500,000. The property tax decreases the city's land area, population, employment density, and population density. Although the tax applies only to residential property, it ultimately affects land rent and land use throughout the city. Land rent at the median CBD location decreases 11 percent (to $26,016 per acre per year), and land rent at the median SRD location decreases 4 percent (to $2,761 per acre per year). Employment density decreases 5.7 percent, and household density decreases 1 percent. The decrease in total land rent is about 160 percent of the total revenue from the property tax. The computer model provides a comprehensive view of the general-equilibrium effects of the property tax.

Summary

1. In the small, open city, the utility level of residents is fixed: any change that increases the relative attractiveness of the city causes in-migration that increases housing and land prices, decreasing utility to its original level.

2. The urban economy achieves general equilibrium when four conditions are met.
   a. Firms make zero economic profit at all locations (guaranteed by the bid-rent functions).
   b. Households achieve the same utility level at all locations (guaranteed by the bid-rent functions).
   c. Land is rented to the highest bidder.
   d. Total demand for labor (from firms in the business district) equals total supply (from residents in the residential district).
3. An increase in the export price shifts the business bid-rent function upward, increasing labor demand as the size and the density of the CBD increase.
   a. The excess demand for labor increases the wage.
   b. The increase in the wage shifts the residential bid-rent function upward, increasing the quantity of labor supplied as the size and the density of the SRD increase.
   c. The increase in the wage also shifts the business bid-rent function downward, decreasing the quantity of labor demanded as the size and the density of the CBD decrease.
   d. The wage continues to rise until labor supply equals labor demand.
4. The streetcar system decreases the slope of the residential bid-rent function, tilting it upward. The size and the density of the residential district increase, increasing total labor supply.
   a. The excess supply for labor decreases the wage.
   b. The decrease in the wage shifts the business bid-rent function upward, increasing the quantity of labor demanded as the size and the density of the CBD increase.
   c. The decrease in the wage shifts the residential bid-rent function downward, increasing the quantity of labor supplied as the size and the density of the SRD decrease.
   d. The wage continues to drop until labor supply equals labor demand.
5. In general equilibrium, city residents are no better off with the streetcar. Migration to the open city decreases wages and increases the prices of housing and land, offsetting the benefits of the streetcar.
6. The property tax decreases the slope of the residential bid-rent function, decreasing the supply of labor as the residential district decreases in size and density. In general equilibrium, the property tax decreases the city's size, density, and total land rent.

Exercises and Discussion Questions

1. Suppose that the intracity truck is introduced into the traditional monocentric city, decreasing the cost of intracity freight. Depict graphically the partial-equilibrium and general-equilibrium effects of the truck.
2. Consider the city of Swampville, a city that recently drained a swamp near its city center and thus increased the supply of developable CBD land by 10 percent. Predict the effects of the draining of the swamp on (*a*) land rent in the CBD, (*b*) land rent in the residential district, (*c*) employment density, (*d*) residential density, (*e*) the equilibrium wage, and (*f*) total employment.
3. Consider a traditional 19th-century monocentric city with a CBD radius of one mile. In 1869, buildings at the edge of the CBD are four stories tall. In 1870, all the buildings in the CBD are destroyed by an earthquake. The mayor of the city announces that in the rebuilt city (*i*) the maximum building height will be four stories and (*ii*) business development will be confined to a circle with a one-mile radius: the radius of the CBD is fixed at one mile. Discuss the effects of the height restriction on (*a*) the demand for labor, (*b*) the supply of labor, (*c*) the equilibrium wage, (*d*) residential density, and (*e*) the city radius.
4. Suppose a city restricts the heights of its residential structures. The maximum building height is four stories, the height that would normally occur at a distance of five miles from the city center.
   a. Draw two residential bid-rent functions, one for the city in the absence of height restrictions and one with height restrictions.
   b. Discuss the effects of the height restrictions on wages, total employment, and land rent in the CBD.
5. Suppose a city imposes a gas tax of $1 per gallon and uses the increase in tax revenue to decrease other taxes. The tax liability of the typical resident is unchanged by the change in tax policy.
   a. Draw two residential bid-rent functions, one before the gas tax and one after the tax is imposed.
   b. Discuss the effects of the gas tax on wages, total employment, and land rent in the CBD.
6. Suppose that the government subsidizes the construction of radial highways. How will such a policy affect land rent, land use, and wages in cities?
7. Suppose that the government subsidizes the production of agricultural products. How will such a policy affect land rent, land use, and wages in cities?
8. Suppose a city builds a streetcar system and passes a law that prevents any outsiders from moving to the city. In other words, the city keeps its population at its pre-streetcar level, so it is a "closed" city instead of an open one. Depict graphically the partial-equilibrium and general-equilibrium effects of the streetcar in the closed city.
9. Chapter 6 (Urban Economic Growth) uses a supply-demand model to depict the urban growth process.
   a. Use the supply-demand model to depict the general-equilibrium effects of the streetcar shown in Table 9–2. Be sure that your picture matches the numbers in the table.
   b. Compute the elasticity of labor demand with respect to the wage.
10. Use a graph to show the partial-equilibrium effects of a tax on business property. Outline the general-equilibrium effects of the business property tax. How do these general-equilibrium effects of the business property tax differ from the effects of the residential property tax?

11. Consider a rectangular city with the following characteristics:
    - *i.* The city is two miles wide.
    - *ii.* The CBD is on a harbor, and the SRD stretches to the east of the CBD.
    - *iii.* Manufacturers transport their output from factories to the CBD docks by horse-drawn wagon.
    - *iv.* Labor demand is a fixed 2,000 workers per square mile (no factor substitution).
    - *v.* Labor supply is a fixed 500 workers per square mile (no consumer or factor substitution).
    - *vi.* In the initial equilibrium, the wage is $10, the CBD is one mile long, and the SRD is four miles long.

    a. Draw the bid-rent functions consistent with the assumptions above.
    b. Show that the city is in equilibrium with a one-mile CBD and a four-mile SRD.

    Suppose that the intracity truck replaces the horse-drawn wagon. The partial-equilibrium effect of the truck is to increase the CBD's length by 0.50 miles.
    c. Depict graphically the partial-equilibrium effect.
    d. What is the partial-equilibrium effect on the labor market: by how much does labor demand exceed labor supply?
    e. Will the wage increase or decrease?
    f. The table below lists the length of the CBD and the length of the city for different wages. What is the new equilibrium wage for the city?

Wage ($ per hour)	*CBD Length (miles)*	*SRD Length (miles)*	*City Length (miles)*
10.0	1.50	4.0	5.50
11.0	1.42	4.3	5.75
12.0	1.33	4.7	6.00
13.0	1.25	5.0	6.25
14.0	1.17	5.3	6.50

References and Additional Readings

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