The Economics of Urban Sprawl

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Although share of US land area occupied by cities is small (around 2%), amount of developed land is growing rapidly (at 2.5 percent per year over 1976-1992 period, for example).

In many cities, rate of spatial expansion far exceeds rate of population growth.

This process of urban sprawl has been criticized in the US, and criticism is now starting in other countries.

Urban spatial expansion is viewed as paving over the landscape, leading to

- undesirable loss of farmland
- loss of open space and its benefits
- more air pollution from longer commutes
- reduced incentives for downtown redevelopment (blight)

Sprawl is also alleged to have undesirable behavioral impacts:

- less social interaction
- more obesity

In response to these concerns, US land-use policies increasingly restrict urban expansion.

Policies include urban growth boundaries, public purchases of vacant land, development fees.

European policies have apparently been restrictive for longer (e.g. green belts in U.K.)

Although sprawl criticisms may sound right, we might ask:

- Are the criticisms well-founded from an economic perspective?
- Do cities really take up too much space?
- Should anti-sprawl measures really be adopted?

The tools of urban economics give answers.

Basic Urban Model

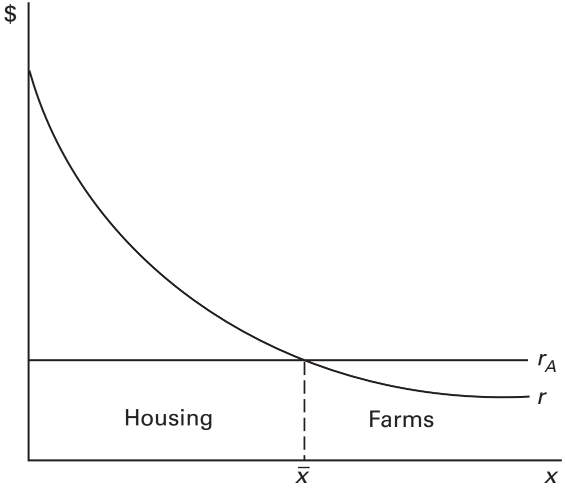
In the monocentric-city model, everyone commutes to jobs in CBD.

Since suburban residents commute farther at higher cost than central residents, compensation is required in the form of lower suburban land rents.

So urban land rent r declines as distance x from the CBD increases.

Housing developers compete with farmers for use of the land, who pay r_A per acre for land.

Edge of city is where urban land rent falls to r_A (boundary distance equals $\overline{x}$).


$
r_A
r
Housing
Farms
$\bar{x}$
x

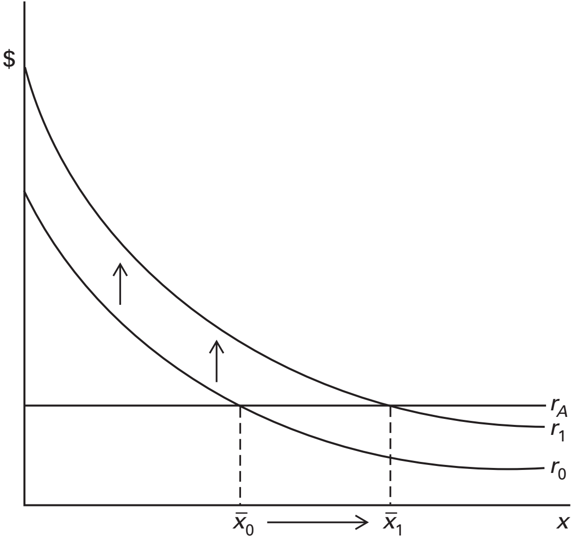
Comparative-static analysis

Comparative-static analysis of the mathematical version of the urban model shows how $\overline{x}$ depends on

- the urban population size, L
- agricultural rent, r_A
- commuting cost per mile, t
- resident income, y

First result is $\partial \overline{x} / \partial L > 0$ (city expands with larger population).

Excess demand for land causes upward shift in land-rent curve.

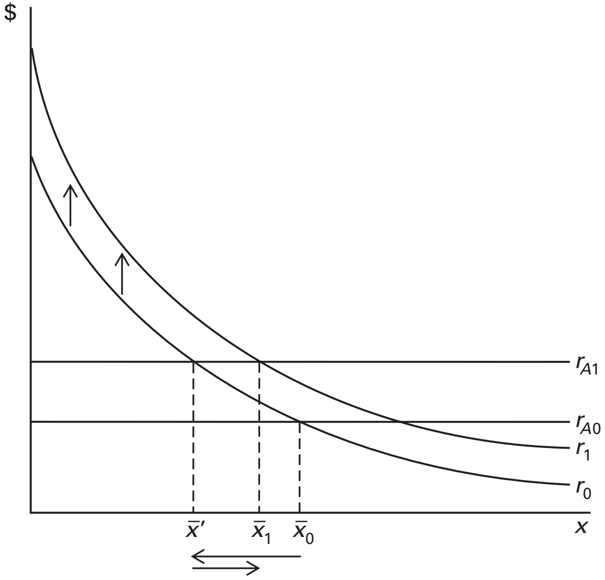

$
r_A
r_1
r_0
$\bar{x}_0$
$\bar{x}_1$
x

Second result is $\partial \overline{x} / \partial r_A < 0$ (city shrinks with higher agricultural rent).

Land rent curve shifts up as population packed in smaller area.

Implication: high-productivity agricultural land more resistant to urban expansion than low-productivity land.

Allays concerns about farmland loss.



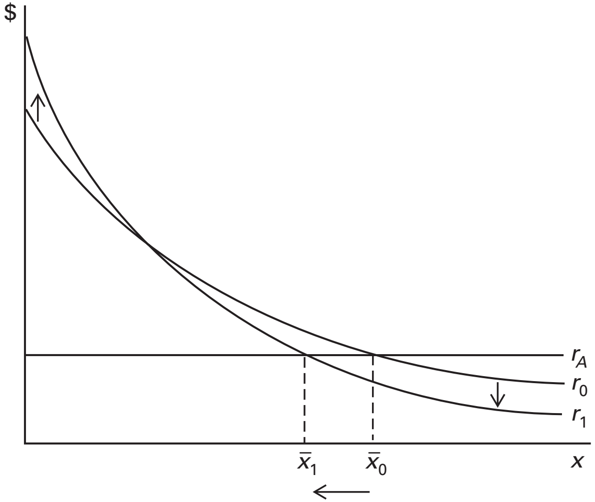
$
r_{A1}
r_{A0}
r_1
r_0
$\bar{x}'$
$\bar{x}_1$
$\bar{x}_0$
x

Third result is $\partial \overline{x}/\partial t < 0$ (city shrinks with higher commuting cost).

More-costly commuting pulls residents toward CBD (land-rent curve rotates clockwise).

Last result is $\partial \overline{x}/\partial y > 0$ (city expands with higher income).

Higher income raises demand for land (land-rent curve rotates counterclockwise).



$
r_A
r_0
r_1
$\bar{x}_1$
$\bar{x}_0$
x

Model identifies main sources of urban spatial expansion experienced in US and elsewhere:

- rising city populations
- rising incomes
- falling commuting costs, a result of freeway investment

Sprawl is mainly driven by these fundamental forces.

Empirical evidence

Conclusions are natural, but what about concrete empirical evidence?

Brueckner and Fansler (1983) and McGrath (2005) regress urbanized land areas on measures of L, r_A, t and y.

BF use 1970 cross section of 40 medium-size cities; McGrath uses decadal panel data on 153 cities over 1950-1990.

Elasticities of urban area land with respect to various variables.

	Brueckner and Fansler (1983)	McGrath (2005)
Population (L)	1.10	0.76
Commuting cost (t)	0	–0.28
Income (y)	1.50	0.33
Agricultural rent (r_A)	–0.23	–0.10

In different approach, Baum-Snow (2007) relates central-city population loss to the number of radial highways connecting center to suburbs.

Negative relationship confirms connection between population decentralization and freeway investment.

Market Failures and Sprawl

Although the fundamental forces clearly drive urban spatial expansion, could they be distorted by market failures?

Result would be cities that take up more space than they should.

Open-space amenities

Under one market failure, urban developers fail to take account of the amenity benefits from open space in their decisions.

This failure leads to excessive urban expansion, as follows.

Suppose each acre of open space yields amenity benefits of b.

Then the true loss from development is forgone agricultural rent plus b.

How to get city to shrink?

Development tax of b, or urban growth boundary (UGB) at correct $\overline{x}$.

Potential criticism: people may not care about open space at urban fringe (city parks matter instead).

Zealous policymaker who does care and imposes UGB causes social harm (people are packed into smaller area paying higher rents for no good reason).

Unpriced road congestion

Another market failure is unpriced road congestion.

With congestion externality, an added car on freeway slows down each other car slightly, produced nonnegligible total effect.

Social cost of commuting then higher than private cost.

So commute trips are too long, and city is too spread out.

Remedy: impose congestion toll, which charges each driver for externality damage.

Similar to an increase in t, and leads to a spatial shrinkage of city.

Little doubt about practical relevance of congestion externality.

Model simulations show that city radius is about 10% too large.

Required toll is about \$0.17 per mile; greatly increases central densities.

Mispriced urban infrastructure

Urban infrastructure may be produced under decreasing returns to scale.

Sewer extensions may be more costly per mile, for example, as network spreads away from center.

But infrastructure costs are spread over all households, with each paying average cost.

Charge is then less than marginal cost, leading to excessive development.

Remedy is impact fees, which make each house pay marginal cost.

Other distortions affecting city sizes

- tax subsidies to homeowners (+ raise demand for land)
- US subsidies to auto travel (+ encourage long commutes)
- agricultural price supports (− raise r_A)

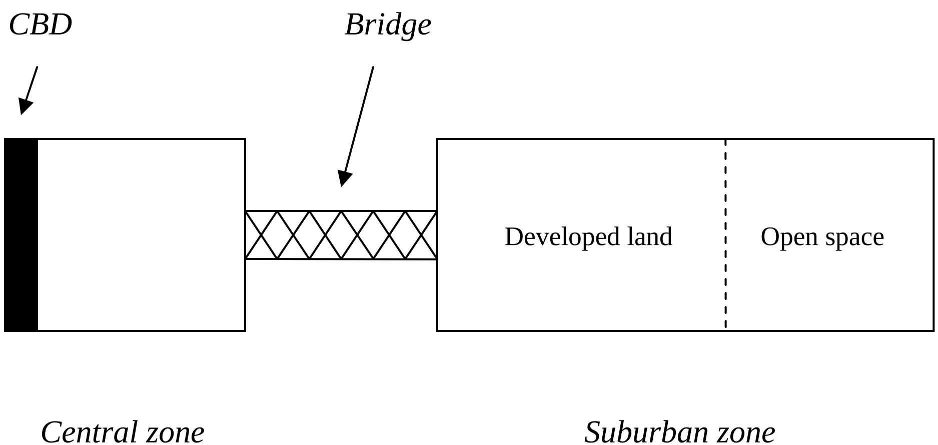
Mathematical analysis using simplified model

To show how the congestion externality causes sprawl, can use simple model adapted from Brueckner and Helsley (2011).

Two zones, central and suburban, with CBD at center's end.

The central zone's area is normalized to 1.

No intrazonal commuting cost, but suburban residents incur cost t of crossing bridge between zones.


CBD
Bridge
Developed land
Open space
Central zone
Suburban zone

Direct consumption of land, with rent r_c in central zone, and r_s in suburban zone ($\overline{r}$ is agricultural rent)

Land consumption levels given by q_c and q_s.

Zone populations are n_c and n_s (total equals N).

Quasi-linear preferences: $U(e, q) \equiv e + v(q)$, where e is nonland expenditure.

With traffic congestion, the bridge cost t is a function of n_s: $t(n_s)$, where $t', t'' > 0$.

Equilibrium conditions

Conditions are

$$v'(q_s) = r_s$$

$$v'(q_c) = r_c$$

$$n_c + n_s = N$$

$$r_s = \overline{r}$$

$$n_c q_c = 1$$

Equilibrium is assumed to leave vacant land in suburban zone.

In addition, utility must be same across zones: $e_c + v(q_c) = e_s + v(q_s)$.

Since $e_c = y - r_c q_c$ and $e_s = y - t(n_s) - r_s q_s$, equal-utility condition reduces to

$$v(q_c) - r_c q_c = v(q_s) - \overline{r} q_s - t(n_s)$$

Eliminating r_c using f.o.c. and using $n_s = 1 - N/q_c$, condition reduces to

$$v(q_c) - v'(q_c) q_c = v(q_s) - \overline{r} q_s - t(1 - N/q_c)$$

With q_s fixed by $v'(q_s) = \overline{r}$, this condition determines q_c and thus the rest of the unknowns.

Optimality conditions

Congestion externality is ignored by suburban commuters, but social optimum takes it into account.

Goal is to minimize resource expenditure subject to fixed (and equal) zone utility levels.

Lagrangean is

$$
\begin{aligned}
\Phi \;=\; (N-n_s)e_c \;+\; n_s e_s \;&+\; \overline{r}(1+n_s q_s) \;+\; n_s t(n_s) \\
&+\; \lambda(e_c + v(q_c) - u) \\
&+\; \mu(e_s + v(q_s) - u) \\
&+\; \rho([N-n_s]q_c - 1).
\end{aligned}
$$

F.o.c.'s same as equilibrium conditions, except that analog to equal utility condition is

$$
e_c \;+\; \rho q_c \;=\; e_s \;+\; \overline{r} q_s \;+\; t(n_s) \;+\; n_s t'(n_s)
$$

Says that the resource cost of locating extra person should be equal across zones (ρ is shadow price of central land).

Eliminating e's via utility constraints and cancelling u yields

$$v(q_c) \ - \ v'(q_c)q_c \ = \ v(q_s) \ - \ \overline{r}q_s \ - \ t(n_s) \ - \ n_s t'(n_s).$$

Same as equal-utility condition except for presence of $n_s t'(n_s)$ on RHS.

To make equal-utility and optimality conditions coincide, must charge suburban residents $n_s t'(n_s)$.

Represents congestion toll: increase in cost per commuter due to an extra commuter (t') times number affected.

Effect of toll

How does toll affect distribution of population between center and suburbs?

Eliminating n_c yields

$$v(q_c) - v'(q_c)q_c \;=\; v(q_s) - \bar{r}q_s - t(1 - N/q_c) - \underbrace{(1 - N/q_c)t'(\cdot)}_{new term}$$

The q_c value in the untolled equilibrium ($\widehat{q}_c$) satisfies this equality in the absence of new term.

But with new term present, LHS exceeds RHS when $q_c = \widehat{q}_c$.

Since LHS is increasing in q_c when $v'' < 0$ and RHS is decreasing in q_c when $t'' > 0$, lowering q_c below $\widehat{q}_c$ will achieve equality.

Therefore, the socially optimal q_c, denoted q_c^*, is smaller than the value $\widehat{q}_c$ in the untolled equilibrium.

Since $n_s = 1 - N/q_c$, it follows that n_s is larger in the untolled equilibrium than at the optimum.

Imposing congestion toll (which achieves optimum) thus causes population to shift toward the center.

Since q_s is same with and without toll, untolled city is too spread out.

Open-Space Amenity

With this kind of amenity, term $\theta(\ell - n_s q_s)$ is added to both utility expressions, where ℓ is total area of suburban zone.

Congestion is absent, so that bridge cost independent of n_s.

Now optimality condition for choice of q_s is

$$v'(q_s) = \overline{r} + \theta N$$

Loss of a unit of suburban land creates a utility loss of θ for each of city's N residents (part of land's opportunity cost).

Since other conditions are same as before, optimum can be generated by imposing a development tax of θN per unit of suburban land, which is passed on to consumers.

Same kind of analysis as before shows that development tax reduces n_s.

Since q_s also falls, city contracts.

Mispriced Infrastructure

Now add urban infrastructure, dropping amenity.

Cost is fixed in center given fixed area, but cost per unit of suburban land serviced is $I(n_s q_s)$, an increasing function of the developed suburban land area.

Total cost of suburban infrastructure is then $n_s q_s I(n_s q_s)$.

Since this cost must be included among the resource expenditures in Lagrangean, optimality condition for q_s becomes

$$v'(q_s) \quad = \quad \overline{r} + I(n_s q_s) + n_s q_s I'(n_s q_s).$$

Last two terms are marginal infrastructure cost from servicing another unit of land.

Traditionally, infrastructure is financed through average-cost pricing, via a tax of $I(n_s q_s)$.

Leads to an f.o.c. for q_s of

$$v'(q_s) \quad = \quad \overline{r} \, + \, I(n_s q_s).$$

To generate optimum, average-cost tax on RHS must be replaced by impact fee capturing marginal cost.

Previous type of analysis shows that n_s falls when the impact fee is imposed, as does q_s.

So city contracts.

When Does UGB Work?

Argued earlier than UGB can be used to generate optimum in case of open-space amenity.

Here, UGB requires $n_s q_s \leq z$, where z is maximum amount of land available for development.

With binding UGB, r_s no longer equals $\overline{r}$, being pushed up by restricted land supply.

Was shown that, in both amenity and infrastructure cases, optimum requires the appropriate wedge between $\overline{r}$ and $v'(q_s)$.

If z under UGB is set equal to $n_s^* q_s^*$ (where * denotes socially optimal value), r_s rises above $\overline{r}$ by exactly the right amount

So optimum emerges.

But UGB cannot support optimum in congestion case.

In that case, no wedge is needed between r_s and $\overline{r}$, but UGB generates one.

Reduces q_s and raises suburban density.

But main goal is a big increase in central density, which is needed to reduce congestion on bridge.

Higher suburban density interferes with goal's achievement.

Brueckner (2007) demonstrates point in a more realistic model.

Adding blight

Brueckner and Helsley (2011) add central-zone building maintenance and reinvestment in a dynamic version of this model.

Show that with any of the three market failures, center has inefficiently low building reinvestment, implying blight.

Imposing corrective policy reduces central blight in each case.

Hortas-Rico (2015) tests this prediction using data on “urban containment” policies (UCP) and urban blight.

For a sample of 125 US cities, she has data on whether the city has a UCP and on a variety of blight measures (percent of residences with broken windows, with holes in roof, etc.).

She regresses various blight measures on UCP and other city characteristics (using IV approach), finding predicted negative effects.

Emissions externalities and sprawl

Emissions externalities, both from commuting and residences, can lead to overexpansion of cities.

Borck and Brueckner (2016), following the engineering literature, assume that residential emissions depend on building surface area.

Calls for tax on the building footprint (effectively a land tax) and a tax on floor space.

Commuting tax also levied.

Three taxes are together equivalent to a carbon tax.

Rates of three taxes are determined from realistic emissions parameters and standard of estimate social damage from emissions.

Simulation shows that combination of three taxes leads to a 9% reduction in the city's spatial size and 4.5% reduction in emissions per capita.

Behavioral Impacts of Urban Sprawl

Social interaction

Many commentators claim that low-density suburban living reduces social interaction by spreading people out.

If low densities reduce interaction, then an externality arises in the choice of land consumption that causes cities to be too spread out.

Preferences are $U(e_i, q_i, I_i)$, where I_i is social interaction experienced by i.

Interaction is the same for all, and suppose it increases with average density: $I_i = f(n/A)$, where $f' > 0$, n is population and $A = \sum q_j$ is city area.

Consumer maximizes

$$U\left[y - \overline{r}q_i,\ q_i,\ f\left(n/\sum q_j\right)\right].$$

by choosing q_i, taking the lot sizes of other consumers, q_k, $k \neq i$, as parametric.

The first-order condition, after imposing symmetry in land consumption, is

$$\frac{U^q}{U^e} = \bar{r} + \frac{f'}{nq^2}\frac{U^I}{U^e}. \quad (3)$$

Says that lot size is optimal when the consumption benefit from a marginal increase in q equals $\bar{r}$ plus a cost from reduced interaction.

Because consumers ignore externality, equilibrium is inefficient.

Social optimum found by imposing symmetry at the outset and maximizing $U[y - \overline{r}q,\ q,\ f(1/q)]$ (density is $n/nq = 1/q$). Optimality requires

$$\frac{U^q}{U^e} \;=\; \overline{r} \;+\; \frac{f'}{q^2}\frac{U^I}{U^e}$$

Since $n > 1$, interaction-cost term is larger than in equilibrium condition, making MRS larger at optimum.

Means that socially optimal lot size is smaller than equilibrium size, so that equilibrium spatial size of city is too big.

Does high density really increase social interaction?

Brueckner and Largey (2008) provide a test.

Combine individual social-interaction information from Social Capital Benchmark Survey with census-tract density data.

Data covers individuals from many different cities.

A number of different interaction measures, denoted M_i, are used as dependent variables

C_j is vector of personal characteristics for respondent j and D_j is population density of his census tract. Regression for measure i is

$$M_{ij} = \beta_i C_j + \gamma_i D_j + \epsilon_{ij}$$

Potential endogeneity problem: people choose tract density in deciding where to live.

IV approach used to avoid possible bias, with instrument equal to average density for city in which tract is contained.

Out of 10 interaction measures studied, density effect is significantly negative for following 6:

- how often respondent talks to neighbors
- number of people that respondent can confide in
- frequency of entertaining friends at home
- respondent belongs to hobby club
- frequency of club meetings
- number of groups to which respondent belongs

For remaining 4 measures, density effect is zero (insignificant).

So, contrary to assertions, low density living raises social interaction.

Obesity

Various studies explore the connection between individual obesity and urban sprawl.

O_j is obesity measure for person j, C_j is vector of other personal characteristics, and S_j is sprawl measure for j's location.

Regression is

$$O_j \;=\; \theta C_j \;+\; \delta S_j \;+\; \eta_j$$

Example is Ewing et al. (2003), who assign a composite sprawl index for the county of residence to each individual.

Find that obesity indicator and BMI value rise with extent of sprawl in county.

Ewing et al. ignore possibility of self-selection: people's residential choice may depend on tendency toward obesity.

Obese people may prefer suburban locations since less walking is required than in central city.

Means that error term η_j in regression (capturing unobservable tendency toward obesity) is positively correlated with S_j, leading to upward biased δ estimate.

Eid et al. (2008) correct for self-selection by using panel data on individuals.

Find that Ewing-style regression produces positive sprawl effect.

But when individual fixed effects are included (possible because of panel structure), sprawl's impact on obesity is zero.

With fixed effects, δ is identified by people who moved between locations with different sprawl measures.

Such people show no change in obesity.

Other Definitions of Sprawl

Eid et al. (2009) define sprawl as "scattered development," an approach also used by some other researchers.

Their sprawl measure is the percentage of undeveloped land in the square kilometer around residence.

Computed by satellite imagery, using results of their previous paper, Burchfield et al. (2006).

Different from density measure or Ewing-style index.

So, instead of focusing on excessive amount of developed land, focus is on “compactness” of development.

Authors run a regression to find determinants of compact development.

Find that cities are more compact (less sprawled) when

- central employment is high
- streetcar passengers high in 1902

- population growth rate is high and stable
- urban fringe has rugged terrain
- fringe areas are incorporated

Some urban planners have yet a different definition, equating sprawl with “unaesthetic” development (strip malls, etc.).

Not a very useful definition from empirical perspective.

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