How Congestion Pricing Reduces Property Values

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Abstract

Congestion tolls which increase an individual's cost of commuting will reduce the number of commuters, and therefore reduce demand for housing within commuting distance of the employment center. Aggregate property values will therefore decline, generating opposition even to congestion tolls which are efficient.

1 Introduction

A large literature demonstrates that congestion tolls can increase aggregate welfare (see Walters (1961), Weitzman (1974)). Nevertheless, congestion tolls are rarely observed, with Singapore the notable exception. Why the opposition to congestion tolls? One important explanation is that a policy of imposing a congestion toll without redistributing the revenue to users will make some consumers worse off (see Weitzman (1974), Glazer (1981), and Niskanen (1987)).

In particular, if all consumers suffer identically from a delay, then a toll that is not returned to consumers necessarily reduces the welfare of all consumers (see Weitzman (1974)). In a more recent statement of the result (which corrects an error by deMeza and Gould (1987)), Evans (1992) notes that a congestion toll cannot increase the welfare of all consumers. For the welfare of some consumers can increase only if fewer persons use the road.

But that will happen only if the costs (toll costs plus time costs) increase for at least some users. These persons are necessarily worse off.

Implicit in these analyses is the thought that when toll revenue is appropriately redistributed, the policy can improve the welfare of all. The intuition behind this reasoning is attractive: when a policy, such as a congestion toll, increases aggregate welfare, it can potentially increase everyone's welfare. The papers analyzing the welfare improvements engendered by congestion tolls have not, however, considered the effects of a congestion toll on property values.

This paper analyzes the effects of congestion tolls on property values, with the purpose of understanding who would benefit and who would lose from the tolls. One might think that since a congestion toll enhances economic efficiency, it would increase aggregate property values. But transportation improvements can reduce the benefits of living close to the Central Business District (CBD), and so can reduce property values.

The effects of transportation on property values are examined by Mohring (1962), who shows that better or more roads can reduce aggregate property values. Arnott and Stiglitz (1981) extend these results, showing that in a linear city with linear transportation costs, aggregate transport costs equal aggregate land rents. Our paper applies this insight to examine the effects of congestion pricing. Kanemoto (1980) notes that a congestion toll increases the transport costs of living at less accessible locations, which should increase property values in the CBD. But he, unlike us, does not consider how a decrease in the number of commuters affects property values.

Congestion tolls need not always affect transportation costs, and therefore need not affect property values. Arnott (1998) notes that in the basic bottleneck model, an optimal congestion toll coupled with no redistribution of the toll revenue has no effect on trip price, since the efficiency gains exactly equal the toll revenue collected. The tolls would therefore have no effects on property values. This assumes, however, as is common in bottleneck models, that the total number of commuters is fixed. Lastly, Small (1992) notes that a congestion toll could cause losses in property value to some landowners, but he does not analyze how.

One application of the analysis is to explain political opposition to congestion tolls. Rather than looking only at the welfare of commuters before and after the toll, or at the distribution of the toll revenue, we also look at the induced changes in property values. These changes are not merely the present discounted values of the first two effects, and can be large.

2 Assumptions

We consider a combination of the "closed city" and the "open city." The population size is fixed, but the number of commuters is variable. The transportation problem is set in a basic, discrete, version of the standard monocentric city model. The Central Business District (CBD) is at one end of the line, at location 0.

The location of a household is indicated by subscript k. The number of households in the city is fixed. Housing quality is independent of location: the lot size is fixed and uniform across space. For the moment we shall consider a one-period model. Later we shall show how property values affect consumption when generations overlap.

A person can work either in the CBD or in the suburbs. The wage in the CBD exceeds the wage in the suburbs by w. Timothy and Wheaton (2001) find a 6.15% wage difference between the Boston CBD and nearby employment centers. The figure for Minneapolis is 2.2%. These differences are related to commuting time differences of 9.7% in Boston and 4% in Minneapolist. For the Chicago Metropolitan area, Carlson and Persky (1999) find that women working in the suburbs earn 7.8% less than those working in the CBD. The difference for male workers is 1.2%.

Working in the suburb involves no commuting cost. Working in the CBD requires commuting from home to the CBD. The commuting cost from location k consists of a time cost T_k and of a toll τ_k. The price of a house at location k is P_k, which will be determined endogenously. Non commuters live in locations whose alternative value is zero, and so pay nothing for property. (Of course, the model could be easily extended to consider a positive value.)

Call the wage in the suburb w_s; the wage in the CBD is $w + w_s$, with $w > 0$. Then the reduced form utility in period 1 is $U = \max(w_s, w_s + w - (T_k + \tau_k - rP_k))$. In any equilibrium in which some people work outside the CBD, all households must enjoy the same utility, namely $U(w_s)$.

3 Results

Since in equilibrium all people enjoy the same utility, commuters living in different locations must also enjoy the same utility. A household at location k will commute if $T_k + \tau_k > w$. The number of commuters, N, is the largest integer which satisfies this inequality.

For simplicity, let the time cost of travel, exclusive of congestion within the CBD, from location k be k. Let congestion occur only at the CBD, and let the toll, τ, be imposed only at the entrance to the CBD. Since the added travel time from location $k+1$ compared to location k (with $k \leq N$) is 1, the rental value of location k must be one more than the rental value of location $k+1$. And since a person at location $N+1$ does not commute, the rental value there is zero. Thus, the rental value at N is 1, the rental value at $N-1$ is 2, and so on. More generally, the rental at location k (with $k \leq N$) is $N-k+1$.[1] Rental values at locations more distant than N are zero. Aggregate rental values are $R = \sum_{k=1}^{N} N-k+1 = N(N+1)/2$.

Consider any toll, τ. This toll increases a commuter's cost of travel. The change in costs consists of two parts. First, he must pay the toll. Second, the toll induces fewer persons to commute, thereby reducing congestion and reducing the time cost of travel. The net effect, however, must be an increase in costs. For were it otherwise, were the cost to decline, more people would commute, increasing congestion; combined with the toll, the costs of commuting would increase, and not decrease.

The effect of a toll can therefore be examined by seeing how the number of commuters, N, changes. If the number of commuters is large, then viewing N as a continuous variable is a good approximation, we can write the function $N(\tau)$, and take its derivative. We obtain

$$\frac{dR}{d\tau} = \frac{d(N)(N+1)/2}{dN}\frac{dN}{d\tau} = (N(\tau)+1/2)N'(\tau). \tag{1}$$

Contrast this to the effect of a toll on toll revenue. The toll revenue is $\tau N(\tau)$, and the derivative is

$$\frac{d\tau N(\tau)}{d\tau} = \tau N'(\tau) + N(\tau). \tag{2}$$

3.1 Comparing toll revenue to change in rental values

We are interested in determining which change is larger in absolute value. As one extreme case, suppose that there is no congestion, so that $N'(\tau) = -\tau$. We then have $dR/d\tau = -(N(\tau)+1/2)\tau$ and $d(\tau N(\tau))/d\tau = -\tau^2 + N(\tau)$.

[1] Coulson and Engle (1987) and, more recently, Chan and Tse (2001) find that time and money costs of commuting significantly affect property price gradients.

Clearly, $dR/d\tau$ is negative. In contrast, an increase in the toll can reduce toll revenue (for example, an increase in the toll to make it prohibitive will reduce toll revenue to zero). To make the problem non-trivial, consider then tolls for which $d(\tau N(\tau))/d\tau > 0$. Then the difference in absolute values is $|dR/d\tau| - |d(\tau N(\tau))/d\tau| = (\tau - 1)N + \tau^2 + \tau/2$. A toll which changes the number of commuters must exceed the cost of travel on the last link, namely 1. Therefore $\tau > 1$ and for sufficiently large N, the change in property values exceeds the change in toll revenue. And note that this can happen even when the toll lies below its revenue-maximizing level.

Consider next a toll on a congestible road. Since the result above is not a knife-edged one, the same qualitative results will hold when the value of $N'(\tau)$ is close to $-\tau$ rather than exactly equal to it; once again a toll imposed on a large number of commuters will reduce aggregate property values.

More generally, consider any toll (which can, but need not be, the socially optimal toll) which reduces the number of users from N_0 to N_1. Let the congestion cost with N users be $c(N)$. If the number of users is N_1 rather than N_0, then it must be that a person living at location N_1 is indifferent about commuting, whereas a person living at location N_0 does not want to commute. Since the time cost of traveling on each link is 1, the difference in time costs of travel between these two locations is $N_0 - N_1$, and therefore the toll which induces this change must be $N_0 - N_1 + c(N_0) - c(N_1)$. A toll which reduces the number of commuters from N_0 to N_1 thus generates toll revenue of $TR = (N_1)(N_0 - N_1 + c(N_0) - c(N_1))$. The reduction in rental values is

$$\Delta R = \sum_{k=1}^{N_0} (N_0 - k + 1) - \sum_{k=1}^{N_1} (N_1 - k + 1) = \frac{(N_0^2 + N_0) - (N_1^2 + N_1)}{2}. \quad (3)$$

To determine whether the change in rental values exceeds the change in toll revenue, we must know the values of $c(N_0) - c(N_1)$. This difference is positive, but without further assumptions we can say no more about its value.

We therefore proceed by making more specific assumptions. Let $c(N) = N^\alpha$, with $\alpha > 1$. Write $N_1 = N_0 - \delta$. Then

$$\Delta R - TR = (N_0 - \delta)^{\alpha+1} + N_0^\alpha(\delta - N_0) + (1/2)\delta(1 + \delta) \quad (4)$$

and

$$\lim_{N_0 \to \infty} (\Delta R - TR) = -\infty < 0 \quad (5)$$

and

$$\lim_{\delta \to N_0} (\Delta R - TR) = (1/2)N_0(N_0 + 1) > 0. \tag{6}$$

That is, the revenue generated by a toll which eliminates almost all commuting trips is less than the drop in rental values. And when the number of initial users is very large, a toll which reduces use generates more revenue than the drop in rental values.

3.2 Effects at socially optimal solution

A central question is whether at the socially optimal toll the reduction in rental values can exceed the toll revenue. The answer is yes. Consider the linear congestion function $c(N) = \theta N$. Social welfare (as a function of N) is $\sum_{k=1}^{N} w - k - \theta N$. Solving the first-order condition yields $N_1 = (2w - 1)/(4\theta + 2)$. The equilibrium condition in the absence of a toll is that $N_0 = w/(1 + \theta)$. We then have $\Delta R - TR > 0$ if $w < (3\theta + 3)/2\theta$. Note first that $\frac{d(3\theta+3)/2\theta}{d\theta} = -3/(2\theta^2) < 0$, so that the smaller is θ the less stringent is the condition that the toll revenue be less than the drop in rental values. Note next that $\lim_{\theta \to 0}(3\theta + 3)/2\theta = \infty$, so that for sufficiently small θ the revenue from tolls when evaluated at its socially optimal value is certain to be less than the drop in property values.

4 Numerical estimate

To figure the empirical importance of the effects, we use stylized data from the literature.

First, from Table 1 in Timothy and Wheaton (2001), the wage difference between CBD and suburban employment is set at 6.15%.

Second, the average commuting time is taken to be half an hour, and the maximum commuting time is taken to be one hour. The average is in line with Table 2 of Timothy and Wheaton (2001). The wage in the CBD is chosen such that commuting times exceeding one hour will induce consumers to work outside the CBD.

Third, a Bureau of Public Roads type of congestion function is used for the link closest to the CBD; all other links are non-congestible. Denoting the time cost of travel for the CBD link by $T(N)$, the formula is

$$T(N) = T(0)\left[1 + \left(\frac{N}{K}\right)^{\alpha}\right], \tag{7}$$

where $T(0)$ is the freeflow travel time cost, N is the number of commuters or traffic flow, K is road capacity, and α is a congestion sensitivity parameter. According to the EMME2 model documentation,[2] a reasonable range for the α parameter is from 2 to 12.

Lastly, a crucial parameter in the model is the capacity, K of the CBD link. We set it so that the time lost in CBD congestion is around 7 minutes.

With these assumptions, the reduction in the sum of aggregate rents and toll revenues at the Pigouvian level of the congestion toll, as compared to the no-toll equilibrium, is 3.7%. Commuting decreases by 16%. If account is taken of an implementation and operation cost for the tolling system equal to 10% of toll revenues (Small and Gomez-Ibanez, 1998), the reduction becomes 6.8%. Smaller values of α and of K lead to smaller reductions in commuting and in the sum of property values and toll revenues. When time lost in congestion is just one minute, the reduction in rents plus toll revenues is 0.15%. For the range of parameter values considered, the sum of changes in rental values and toll revenues is always negative.

5 Extensions

5.1 Location of toll

We so far considered a toll placed at the point of congestion, namely at the CBD. Toll revenues will be positive, but property values at each location will decline. Moreover, since the toll increases any person's private cost of commuting, in the absence of redistribution of the toll revenue, no residents benefit, and some suffer. Redistribution, however, can be costly (either directly, or because of rent seeking efforts), or may not be credible. The result may be popular opposition to a congestion toll.

Many of these difficulties can be alleviated by collecting the toll at a different location. Suppose government wants to reduce the number of commuters from N_0 to N_1 (N_1 can, but need not, represent the socially optimal solution). Let the toll associated with this solution be τ.

[2] www.spiess.ch/emme2/conic/conic.html

Consider the toll of τ imposed not at the entrance to the CBD, but at the link connecting $N_1 + 1$ to N_1. A person living at a distance greater than N_1 from the CBD must now pay the toll, just as he would if the toll were collected at the entrance to the CBD. Moving the toll booth thus does not affect commuting behavior of these people. People living at N_1 or closer need pay no toll. So if they had commuted when the toll was at the CBD, they would commute when the toll is at N_1. In short, commuting behavior is unchanged.

What does change is property values. A toll at the CBD reduced property values at locations lying between the CBD and N_0. A toll at N_1 instead of at the CBD does not affect property values at locations more distant than N_1. But it increases rental values by the amount of the toll at each location between the CBD and N_1. Moving the toll booths from the CBD to N_1 thus effectively redistributes the toll revenue to property owners of locations within distance N_1 of the CBD.

Our previous analysis showed with the toll at the CBD the toll revenue may be less than the fall in rental values. Therefore, a toll at N_1 may also cause aggregate property values to fall. But the drop will not be as large as with a toll at the CBD, and a majority of property owners may see their property values rise. A toll at N_1 may therefore generate greater political support than a toll at the CBD.

5.2 Redistributing toll revenue

We have not yet discussed what happens with the toll revenue. The simplest assumption is that each resident receives a lump sum grant. We might alternatively suppose that congestion tolls are used to reduce property taxes. The reduced taxes will be capitalized into property values, increasing them by the amount of the tax reduction. But since the reduction in property values can exceed the toll revenue, the toll may, in the aggregate, make consumers worse off.

5.3 Effects of property values on consumption

If commuters are infinitely lived then the change in rents does not matter, as the opportunity cost of occupying a house at a given location never materializes. But if commuters in one period choose to become non-commuters in a later period, then changes in property values can have real effects.

We show this with an overlapping generations model. Let each person live for two periods. In period 2 of his life, no one works, and consumes from savings he made in period 1 of his life. A non-commuter stays in the same house over the two periods. A commuter buys a house in period 1 closer to the CBD by borrowing the purchase price. In that period he pays interest r times the purchase price, P_k. In a steady state the price of a house is constant over time, so a homeowner has neither capital gains nor losses. The interest payment thus represents the opportunity cost of owning a particular house. In period 2 he sells the house (to a young person, who commutes in period 1 of his life) repays the loan, and moves towards the edge of the city.

Now consider what happens in a year in which a congestion toll is introduced. The current commuters (call them A) bought property at the land values before the congestion toll was introduced. When generation A retires, it sells the property and moves towards the edge of the city (as commuting is the only rationale for paying positive rents). If no congestion toll is introduced, property values are unchanged and generation B behaves identically to generation A. But with a toll, generation A faces a real welfare loss, as a commuter in generation B is willing to pay less for property within commuting distance of the CBD. The proceeds from selling the property will not suffice to repay the principal of the loan. Therefore current owners-occupants will oppose the introduction of congestion tolls.

6 Conclusion

This paper considered the distributive effects of congestion tolls, showing that the induced changes in property values can be large. Indeed the fall in property values can be so large that the toll revenue would not generate enough money to compensate the homeowners who suffer the loss in property values. Declines in property values need not always cause declines in consumption—property values will not matter if people never sell their houses, or if the economy is closed, with no capital flows and no trade. If, however, residents of a city owe money to outsiders (as is most plausible when we think of bank mortgages), and if they buy goods produced outside the city, then a decline in a consumer's financial wealth will reduce his consumption. A congestion toll can therefore reduce the utility of commuters, and reduce aggregate utility in the city. Political opposition to congestion tolls, or to other forms of road pricing, may therefore be intense. And, of course, a similar analysis applies to removal of a congestion toll. Removing it would increase property values, possibly by even more than the decline in toll revenues. Voters may therefore favor ending a congestion toll were one imposed.

7 Notation

k Location of household

N Number of commuters in the city

P_k Price of house at location k

r Interest rate

T_k Time cost of travel from location k

τ_k Toll from location k

w Wage differential for the CBD

w_S Wage in the suburb

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