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The political economy of urban transport-system choice

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Abstract

This paper analyzes the political economy of transport-system choice, with the goal of gaining an understanding of the forces involved in this important urban public policy decision. Transport systems pose a continuous trade-off between time and money cost, so that a city can choose a fast system with a high money cost per mile or a slower, cheaper system. The paper compares the socially optimal transport system to the one chosen under the voting process, focusing on both homogeneous and heterogeneous cities, while considering different landownership arrangements. The analysis identifies a bias toward underinvestment in transport quality in heterogeneous cities.

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1. Introduction

A frequently heard criticism of local public policy in the US concerns the choice of transport systems. In particular, environmentalists and other activist groups often argue that US cities have overinvested in automobile-oriented transportation infrastructure at the expense of public transit. They argue that urban residents would be better off if past transport investment had favored rail and bus systems, with less money spent on freeways.

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This argument has gained force recently with the emergence of urban sprawl as a policy issue. Critics argue that freeway investment has encouraged excessive spatial growth of US cities.¹

Unfortunately, urban public economics provides almost no insight into the issues surrounding the choice of an urban transport system. Transport costs are viewed as exogenous in the typical urban model rather than being the result of a prior policy decision regarding the nature of the transport system. As a result, the above criticism of transport investment patterns is difficult to evaluate using existing models. To remedy this deficiency, the present paper proposes and analyzes a model where the transport system is chosen endogenously, with the choice carried out in the context of a simple urban general equilibrium framework. The goal of the analysis is to compare the socially optimal transport system to the one selected under the public-choice process.

While transport costs impose a direct burden on consumers, these costs also affect land rents in a general equilibrium model by determining the value of access to the city center. This land-rent impact creates several paths by which the transport system affects consumption. When land rent flows to absentee landowners living outside the city, a transport-induced change in rent affects just the cost of living for consumers. But when consumers are resident landowners, earning as income a share of the city's total land rent, transport-induced rent changes affect both living costs and incomes. Recognizing these differences, one goal of the analysis is to explore how landownership arrangements affect the choice of the transport system.

Transport costs in the model have two components: money cost and time cost. The money cost per mile of travel, denoted t , captures the costs of road construction and automobile operation under a freeway system while representing the analogous construction and operating costs under a public transit system. Time cost, on the other hand, captures the value of the time spent in travel. It depends on the inverse of the transport system's speed, denoted ϕ , being equal to ϕ multiplied by the wage rate. The analysis rests on the fundamental assumption that ϕ is a decreasing function of t , so that the city faces a trade-off between time and money cost in choosing the transport system. To facilitate the analysis, this trade-off is viewed as continuous, with a continuum of transport systems corresponding to different combinations of t and ϕ available to the city. While this assumption is obviously unrealistic, it allows the choice between an expensive, fast freeway system and a cheap, slow bus system to be couched within a continuous optimization problem.

The discussion begins by analyzing transport-system choice in the benchmark case where city residents are homogeneous in their skill levels, thus earning uniform incomes. The analysis shows that the socially optimal system minimizes total transport cost (including time cost). The discussion then demonstrates that the political equilibrium coincides with the social optimum regardless of landownership arrangements. Under the political process, only the urban residents themselves have the right to vote, with absentee landowners (if they exist) having no voice in the city's transport decision.

¹ For an excellent overview of the debate on sprawl, where such ideas can be found, see the urban sprawl symposium in the Fall 1998 issue of the *Brookings Review*.

With no divergence between the equilibrium and the optimum found in the homogeneous case, the analysis turns to the more realistic and complex case of a city with heterogeneous skills. Consumers (represented by a continuum) earn different incomes and thus have different time costs, which means that they have divergent interests in the choice of the transport system. The analysis again shows that the socially optimal system minimizes total transport cost. But consumer heterogeneity eliminates the previous equivalence between the social optimum and the political equilibrium. The analysis shows that, unless the distribution of skills is strongly (and unrealistically) skewed in the direction of low skills, the transport system chosen under the voting process is less expensive and slower than the socially optimal system. Thus, the paper identifies a bias toward transport underinvestment that directly contradicts the allegations of the above critics, who claim that the US has invested too much in freeways at the expense of public transit. This bias is shown to arise regardless of landownership arrangements, although the analysis demonstrates that the extent of underinvestment is larger under resident landownership.

The underinvestment result is due to the model's pattern of residential location by skill type. High-skill consumers realistically live in the suburbs, thus enduring long commutes to the city center. While their high time costs lead high-skill individuals to demand better transport quality (a higher t) holding location fixed, the fact that commute distance rises with skill means that the demand for transport quality increases at an increasing rate as skill rises. This convexity of demand in turn means that the demand curve of the median voter, who has the median skill level, tends to understate society's demand for transport quality, leading to an underinvestment bias.

It is important to recognize that this underinvestment bias could be reversed in the presence of transport subsidies, which are omitted from the model. In reality, public transit fares cover only a share of system costs while gasoline taxes fail to cover the full cost of roads, and the resulting subsidies could be incorporated in the model by writing the money cost of transport as αt , with $1 - \alpha$ being the subsidy rate.² Brueckner (in press) analyzes the effect of money-cost subsidies in a homogeneous model, where they constitute the only source of inefficiency, showing that transport overinvestment is the result. Thus, if subsidies were included in the present model, they would tend to counteract the underinvestment bias that emerges from its heterogeneous structure. While this corrective effect is desirable, indicating that the transport subsidies that exist in practice may be warranted, excessive subsidies could lead to the overinvestment alleged by the critics. Even though the model's predictions are thus ambiguous once subsidies are introduced, the analysis provides an important contribution by exposing key elements in the political economy of transport-system choice.

While the analysis sketched above assumes that the city builds a single transport system, divergence of consumer interests in the heterogeneous case means that construction of several different systems may be welfare-improving. Through numerical examples, the discussion in the last section of the paper shows that two systems should be

² See Borck and Wrede (2004) for an analysis of a model where urban residents vote on the size of transport subsidies.

built when consumer heterogeneity is substantial or when the fixed cost of system construction is low.

Before proceeding to the analysis, some discussion of the antecedents of this paper is useful. The idea of transport-system choice in the face of a continuous trade-off between time and money costs was first introduced and briefly analyzed by Brueckner (in press). Brueckner's paper in turn builds on the earlier work of LeRoy and Sonstelie (1983), who analyze an urban model where residents choose between two exogenously specified transport systems, one with a high money cost and low time cost, and another with the reverse characteristics. Starting from a situation where the city has just one transport system, LeRoy and Sonstelie's analysis shows that introduction of a more expensive, faster system, which is adopted by high-income households but not by the poor, can lead to reversal in the city's pattern of location by income, with the rich relocating to the suburbs. The present analysis relies on LeRoy and Sonstelie's idea of money and time cost differences across transport systems, but it makes use of this trade-off in the choice of an optimal system.³

Like LeRoy and Sonstelie (1983), Sasaki (1989) shows how coexistence of two transport systems affects urban structure, although he assumes a homogeneous city. With the systems differentiated by fixed cost and variable cost per mile (the latter a composite of money and time costs), Sasaki shows that suburban residents favor the high-fixed-cost/low-variable-cost system, while their shorter commutes lead central-city residents to favor the system with the reverse characteristics. By contrast, Sasaki (1990) considers a city with two income groups and allows transport systems to be differentiated by variable money and time costs as well as by fixed costs. He carries out a comparative-static analysis to explore the effect on urban structure of changes in these parameters, but the problem of choosing an optimal transport system is not considered.

The plan of the paper is as follows. Section 2 analyzes the benchmark model with homogeneous urban residents. Section 3 analyzes the heterogeneous model, while Section 4 analyzes the choice of two transport systems in the heterogeneous case. Section 5 offers conclusions.

2. The benchmark model

2.1. *The setup and the social optimum*

The analysis focuses on a linear city of unit width with an employment center (the CBD) at one end. Distance from the CBD is denoted by x . The city is inhabited by N identical residents, each of whom consumes a fixed land area, normalized at unity. With population and land consumption fixed, the area of the city is also fixed, with its edge

³ DeSalvo and Huq (1996) analyze a model where a transport mode's money cost effectively depends on its speed, as in the present analysis (their presentation, however, makes this similarity hard to see). Their analysis focuses solely on the mode choice question, without putting the problem into a spatial setting.

located at distance N . The rent earned by the non-urban land is set equal to zero for simplicity.

In addition to land, urban residents consume a composite non-land good, denoted c , which is produced at the CBD by a constant-returns technology that uses labor as an input. Letting L denote the aggregate labor input (in effective units), the city's output equals yL , where $y > 0$. The labor market is competitive, so that the wage (per effective labor unit) is equal to y . The impact of the alternate assumption of decreasing returns in CBD production is considered below.

In the benchmark model, consumers have homogeneous skills, with each offering an effective labor input of e units (skill heterogeneity is introduced below). While a consumer would earn an income equal to ey in the absence of commuting, the time spent commuting to the CBD reduces actual income below this "full" income level. In the model, this reduction is achieved in the simplest possible way via the assumption that leisure time is fixed, so that an extra minute of commute time reduces work time by 1 min.

To see how time cost is generated via this assumption, recall that since ϕ is the inverse speed of the transport system, a commute trip of x miles requires a time expenditure of ϕx min. Thus, with the total time available for work normalized at unity, work time for this commuter equals $1 - \phi x$, and income equals $ey(1 - \phi x) = ey - ey\phi x$. The last expression equals full income ey minus the value of time lost to commuting, $ey\phi x$, which represents time cost.⁴ Recognizing the potential work hours that are lost to commuting, the total labor input at the CBD equals the integral of $e(1 - \phi x)$ across the city's range of x values, as explained further below.

To finish the characterization of transport costs, recall that t equals the money cost of transport per mile. Since a commute trip of x miles thus entails a money cost of tx , total transport cost inclusive of time cost equals $(ey\phi + t)x$. Disposable income net of transport costs is thus given by $ey - (ey\phi + t)x$.

As made clear in the Introduction, the purpose of the paper is to analyze choice of the transport system, taking the trade-off between time and money cost into account. Formally, this trade-off means that ϕ is a decreasing function of t , written $\phi(t)$. Thus, time cost falls as money cost rises, a consequence of the higher speed of a more costly transport system. The inequalities $\phi' < 0$ and $\phi'' > 0$ then hold, with the latter condition implying that time cost decreases at a decreasing rate as t increases.⁵

A final element of the model is a "taste for location", which is introduced in order to generate in a simple fashion a realistic pattern of location by income in the heterogeneous model, where skills and incomes vary across the population. In particular, preferences are assumed to include a locational benefit term, which is written as βex . If $\beta > 0$, then consumers prefer locations farther from the CBD, with the strength of this preference increasing in the skill level e .⁶ As explained further below, when β is positive and

⁴ While commute time is valued at 100% of the wage under this formulation, empirical evidence indicates that actual rates of valuation are less than 60% (see Calfee and Winston, 1998 for recent evidence).

⁵ It is important to recognize that the characteristics of the transport system are constant across its length. In other words, t is not allowed to vary with x .

⁶ The taste for location could be driven, for example, by a decline with x in the level of air pollution combined with a stronger preference for clean air among high-skill individuals.

sufficiently large, consumers with higher skills and incomes will live farther from the CBD in equilibrium, replicating the pattern typically seen in US cities. For simplicity, locational benefits are assumed to enter preferences in a linear fashion, with utility equal to $c + \beta ex$. As a result, transport cost net of locational benefits can be written as $[e(y\phi - \beta) + t]x$. A maintained assumption is that $e(y\phi - \beta) + t > 0$ holds over the relevant range of e and t values, so that locational benefits are never strong enough to offset the time and money costs of transport. Finally, it should be noted that locational benefits play no role in the ensuing analysis of the homogeneous city, having an effect only in the heterogeneous case.

To begin the analysis of the homogeneous case, consider the choice faced by a planner in choosing the socially optimal transport system. Note first that the city’s aggregate labor input is given by

$$L = \int_0^N e(1 - \phi(t)x)dx = e(N - \phi(t)N^2/2). \tag{1}$$

In Eq. (1), recall that the edge of the city is located at $x=N$, that the city is one unit wide, and that population density is unity given unitary land consumption. The planner’s goal is to choose the transport system to maximize the city’s surplus S , which equals output yL minus aggregate money transport cost plus aggregate locational benefits. Aggregate money transport cost equals $\int_0^N tx dx = tN^2/2$, or average money transport cost $(tN/2)$ times population. Similarly, aggregate locational benefits equals $\int_0^N \beta ex dx = \beta eN^2/2 \equiv B$. Thus, surplus is given by

$$\begin{aligned} S &= y[e(N - \phi(t)N^2/2)] - tN^2/2 + B \\ &= yeN - [e(y\phi(t) - \beta) + t]N^2/2. \end{aligned} \tag{2}$$

Note that the second line of Eq. (2) shows that surplus equals full output minus aggregate transport cost, including time cost, net of locational benefits.

To see that Eq. (2) is the correct welfare measure, recall that the opportunity cost of urban land equals zero. Therefore, the only resource cost incurred in generating the city’s output is the money cost of transport, which must be subtracted from output in computing surplus. In the equilibrium analysis below, it will be seen that S equals total urban consumption plus aggregate land rent plus B , which further confirms the appropriateness of Eq. (2) as the welfare measure.

The socially optimal t , denoted t^* , maximizes surplus. But from Eq. (2), this goal is achieved by choosing t to minimize transport cost per mile, $e y \phi(t) + t$. The relevant first-order condition is $e y \phi'(t) + 1 = 0$, and $\phi'' > 0$ ensures that the second-order condition is satisfied. Recalling that $\phi' < 0$, the first-order condition can be usefully rewritten as

$$- e y \phi'(t) = 1, \tag{3}$$

which indicates that the marginal benefit from an increase in t , given by the LHS, equals its unitary cost. Indeed, the LHS of Eq. (3) can be viewed as the downward-sloping social demand curve for transport-system “quality,” as measured by money cost. The optimal t is characterized by the intersection of this social demand curve with a horizontal line at height one.

The goal of the analysis is to compare the transport system chosen under a public-choice process to the socially optimal system characterized by Eq. (3). Before proceeding to this task, however, several general observations and qualifications regarding the model are useful. First, the money cost of transport should be interpreted in the broadest possible sense. For example, in the case of freeway travel, t should be viewed as including automobile operating costs along with the commuter's share of the annualized construction and maintenance costs of the roads used. For rail transit, t should be viewed as including the cost of train operations as well as the annualized construction costs of railroad tracks. For bus transit, t would include the cost of bus operations and an appropriate share of roadway costs.

Another question concerns the presence of fixed costs. The above framework implicitly assumes that these costs are absent, with the total resource costs of the transport system equal to t times total passenger miles of travel, $\int_0^N x dx$. Alternatively, the transport system might involve a fixed cost of k for each mile of the network, with the variable costs that depend on total passenger miles representing a separate expenditure.⁷ The ensuing analysis is consistent with this alternate view under a particular assumption: the fixed cost k must be independent of t and thus independent of where the system lies along the money-cost/time-cost continuum. In this case, given that the transport system has a fixed length N , fixed costs represent a lump-sum amount kN that can be ignored in the choice of t . It should be noted, however, that fixed costs play a role in the problem considered in Section 4, where the city is allowed to build two separate transport networks to serve a heterogeneous population. The question is then whether a second fixed cost is worth incurring.

2.2. The land–market equilibrium and the choice of t with absentee landownership

Having characterized the social optimum, the next step is to analyze the city's land–market equilibrium, with the goal of finding the t value selected by public-choice process. The initial focus is on the absentee-landowner case, where landowners live outside the city.

Locational equilibrium in the city requires that consumer utility is locationally invariant, equal to a constant u . Thus, $c + \beta ex = u$ must hold, where c again is non-land consumption, which varies with location. This equality is achieved by spatial variation in land rent, as follows. Letting $r(x)$ denote land rent at distance x , consumer expenditure is given by $c + r(x)$, where the assumption of unitary land consumption is used. Substituting for c , expenditure can be written $u - \beta ex + r(x)$. Equating this expression to income net of transport costs then yields the following version of the consumer's budget constraint:

$$u - \beta ex + r(x) = ey - (ey\phi + t)x, \quad (4)$$

Eq. (4) shows that the spatial variation in land rent required to keep utility constant just offsets differences in transport costs net of locational benefits. In particular, using Eq. (4),

⁷ For example, in the freeway context, fixed cost would capture the cost of the median strip, which must be built regardless of the width of the freeway.

the relationship $r(x) - r(N) = [e(y\phi - \beta) + t](N - x)$ must hold. But since $r(N)$, land rent at the edge of the city, must equal land's zero opportunity cost, it follows that

$$r(x) = [e(y\phi - \beta) + t](N - x). \quad (5)$$

Land rent thus declines with x , offsetting the higher (net) transport costs from more distant locations (recall that $e(y\phi - \beta) + t > 0$). Substituting Eq. (5) into Eq. (4), the equilibrium utility level in the city equals

$$u = ey - [e(y\phi(t) - \beta) + t]N. \quad (6)$$

Note that utility equals the consumption of the edge resident, $ey - [e(y\phi(t) + t)N]$, plus locational benefits, βeN .

As explained in the Introduction, consumers dominate the public-choice process that determines the nature of the city's transport system. With population homogeneity, consumer interests in this process are identical, and they call for maximization of the utility expression in Eq. (6). But this maximization requires choosing t to minimize transport cost per mile, $ey\phi(t) + t$, just as in the planner's problem. Therefore, with absentee landownership, the outcome of the political equilibrium is socially optimal, with t set at t^* .

It should be noted that this conclusion involves an implicit assumption regarding the degree of consumer sophistication in the choice of t . In particular, consumers are assumed to understand the structure of the urban equilibrium in making this choice, recognizing that their interests lie in maximizing Eq. (6). This sophistication assumption, which applies perhaps with greater force in the heterogeneous model analyzed below, also appears in other models of the local public-choice process, most notably [Epple and Romer \(1991\)](#).

2.3. The resident-landowner case

Aggregate land rent in the city, denoted R , is equal to

$$R = \int_0^N [e(y\phi - \beta) + t](N - x)dx = [e(y\phi - \beta) + t]N^2/2, \quad (7)$$

where Eq. (5) is used. A key observation is that R is also equal to aggregate transport cost net of locational benefits, which is given by

$$T \equiv \int_0^N [e(y\phi - \beta) + t]x dx. \quad (8)$$

This connection between land rent and transport cost reflects a general property of urban models first noted by [Arnott and Stiglitz \(1979\)](#).⁸

When landowners are absentee, a comparison of Eqs. (6) and (7) reveals that their interests are diametrically opposed to those of consumers. While consumers, seeking maximal utility, prefer the system that minimizes transport cost per mile, the resulting system minimizes the rental income of absentee landowners, thus constituting the worst

⁸ In a circular city, however, R equals one-half aggregate (net) transport cost.

possible outcome from their point of view. Instead, to raise the value of access to the CBD, absentee landowners want a high $ey\phi + t$ and hence an inefficient transport system, with t far away from the value that minimizes cost. Indeed, since R is a U-shaped function, absentee landowners benefit from either high or low values of t . These preferences, however, are not registered in the political process, which is dominated by consumers.

This divergence of interests collapses when the city's land is owned by the residents themselves. Assuming that each individual earns a $1/N$ share of total land rent, the term R/N is then added to the utility expression in Eq. (6). Using Eq. (7), this expression then reduces to

$$\tilde{u} = ey - [e(y\phi(t) - \beta) + t]N/2. \quad (9)$$

The key implication of Eq. (9) is that consumers, acting as resident landowners, again choose t to minimize aggregate transport cost, so that the public-choice outcome again matches the social optimum. In this case, however, the equivalence is due to the exact coincidence of objectives. In particular, total utility in the resident-landowner case, given by $N\tilde{u}$ from Eq. (9), equals the surplus measure in Eq. (2), so that the objective function of resident landowners exactly matches that of the planner.

While this conclusion is natural, the optimality of equilibrium in the absentee-landowner case is more noteworthy. In this case, Eqs. (6) and (7) yield $S = Nu + R = Nc + B + R$, so that surplus equals total consumption plus aggregate land rent plus aggregate locational benefits, as noted above. The objective functions of consumers (u , or Nu) and the planner (S) thus differ in this case, with the difference equal to aggregate land rent. Nevertheless, it is easy to see that, because consumer and landowner interests are diametrically opposed, u and S are both maximized at t^* .⁹

Summarizing the preceding discussion yields

Proposition 1. *In the homogeneous model, the political equilibrium is socially optimal under both absentee and resident landownership, with t chosen to minimize transport cost per mile.*

3. A model with consumer heterogeneity

3.1. The setup and the social optimum

With no divergence between the equilibrium and optimum found in a homogeneous city, the analysis now turns to a more complex model where consumers are heterogeneous

⁹ In the absentee-landowner case, the dominant role of consumer interests in determining the behavior of surplus can be seen as follows. From the consumer budget constraint, total utility is equal to total full income minus aggregate transport cost net of locational benefits minus aggregate land rent. Since aggregate land rent equals aggregate net transport cost, total utility then equals total full income minus twice aggregate net transport cost, so that the consumer goal is to minimize the latter. Surplus, which is found by adding aggregate land rent (and hence aggregate net transport cost) to total utility, thus equals total full income minus aggregate net transport cost (without the factor of 2). Society's goal is thus to minimize the latter quantity, matching the goal of consumers.

in their e values, exhibiting a distribution of labor skills. This model may offer a better representation of real-world cities, and in addition, it generates a new source of divergent interests in the choice of t . In particular, since skill differences generate income differences among consumers and hence differences in the time cost of transport, consumers themselves disagree over the characteristics of the preferred transport system.

A key question in a heterogeneous model concerns the pattern of consumer location by skill and hence income. Under the typical location pattern in US cities, incomes tend to increase with distance from CBD, although this pattern is often reversed outside the US (see Brueckner et al., 1999). As is well known, two forces interact to determine the location pattern by income in the standard urban model (see Wheaton, 1977). On the one hand, a higher time cost of transport pulls higher-income consumers toward central locations. Conversely, their high land consumption pulls these individuals toward suburban locations, where land is cheap. The latter force is thought to dominate in producing the observed US location pattern.

For reasons of tractability, endogenous land consumption cannot be incorporated in the continuum model developed below. As a result, the second of the above forces is not present in the analysis. But the assumption of a skill-dependent taste for location operates in its place, providing a force that pulls high-skill consumers away from the CBD. For this force to dominate the centralizing effect of higher time costs, making residential distance a realistically increasing function of the skill level, $y\phi - \beta < 0$ must hold, as explained further below. While this inequality is assumed to hold over the relevant range of t values, the inequality $e(y\phi - \beta) + t > 0$ must continue to hold in order for transport costs net of locational benefits to be positive (its satisfaction is again assumed over the relevant ranges of e and t values).

As before, the first step in the analysis is to characterize the socially optimal transport system, taking consumer heterogeneity into account. To begin, let the support of the skill distribution be given by the interval $[\underline{e}, \bar{e}]$, and let $g(e)$ and $G(e)$ denote the density and cumulative distribution functions, respectively. Then, consider the assignment of consumers to locations within the city, which must be chosen optimally along with the transport system. As suggested above, residential distance is increasing in e in equilibrium, and the same pattern characterizes the optimum. To establish this fact, suppose that some pair of consumers violates it, with consumer 1, who has a skill of e_1 located at x_1 and consumer 2, with a skill of $e_2 > e_1$ located at $x_2 < x_1$. The combined contributions to CBD output for these two consumers, plus their combined locational benefits, equals $ye_1(1 - \phi x_1) + \beta e_1 x_1 + ye_2(1 - \phi x_2) + \beta e_2 x_2$. However, if the locations of the consumers were switched, output plus locational benefits would be $ye_1(1 - \phi x_2) + \beta e_1 x_2 + ye_2(1 - \phi x_1) + \beta e_2 x_1$ and the change would equal $(y\phi - \beta)(e_2 - e_1)(x_2 - x_1) > 0$. The resulting gain in output plus locational benefits indicates the suboptimality of the initial assignment, establishing that e and x must be positively related.

With the least-skilled consumers living closest to CBD, the residential distance of a consumer with skill e , denoted $x(e)$, is given by

$$x(e) = N \int_{\underline{e}}^e g(v) dv = NG(e), \quad (10)$$

which equals the number of people with skills less than e . The labor supply of a type- e consumer is then $e[1 - \phi x(e)]$, so that the city's total labor input is given by

$$L = N \int_{\underline{e}}^{\bar{e}} e[1 - \phi x(e)]g(e)de = e_m N - \phi N^2 \int_{\underline{e}}^{\bar{e}} eg(e)G(e)de = e_m N - \phi N^2 J, \tag{11}$$

where Eq. (10) is used, $e_m = \int_{\underline{e}}^{\bar{e}} eg(e)de$ is the mean of e , and $J > 0$ represents the last integral in Eq. (11). Note that since $\phi N^2 J \equiv \int_{\underline{e}}^{\bar{e}} e\phi x(e)g(e)de$ represents the potential labor input lost in transport time, the aggregate time cost of transport is equal to $y\phi N^2 J$.

Surplus is again equal to yL minus the total money cost of transport, which still equals $tN^2/2$, plus aggregate locational benefits, which equals $N \int_{\underline{e}}^{\bar{e}} \beta ex(e)g(e)de = \beta N^2 J$. Thus, using Eq. (11),

$$S = ye_m N - [2J(y\phi(t) - \beta) + t]N^2/2, \tag{12}$$

which equals full income minus aggregate transport cost net of locational benefits, as in Eq. (2).¹⁰ As a result, maximizing S again requires minimizing aggregate transport cost, and the appropriate condition is

$$-2Jy\phi'(t) = 1. \tag{13}$$

Note that society's demand curve for transport quality, as represented by the LHS of Eq. (13), involves a different skill term ($2J$) than in the homogeneous case (compare Eq. (3)).

3.2. Characterizing the land–market equilibrium

Having analyzed the social optimum, the next step is to characterize the land–market equilibrium of the heterogeneous city, a task that is more involved than in the homogeneous case. The central idea, following the approach of [Brueckner et al. \(2002\)](#) and [Selod and Zenou \(2003\)](#), is that utility levels must vary with e in such a way that the individual with a particular e value offers the highest bid for the land at $x(e)$, where he must reside. The initial analysis focuses on the absentee-landowner case.

Let $c(e)$ and $u(e)$ denote the consumption and utility levels for an individual with a given e value, which satisfy $c(e) = u(e) - \beta ex$. Then, rearranging a budget-constraint equation analogous to Eq. (4), the land rent this individual offers at location x is given by

$$r(x, e) = ey - [e(y\phi - \beta) + t]x - u(e). \tag{14}$$

Note first that, for a given e , this land-rent function is linear in x and has slope equal to $-[e(y\phi - \beta) + t]$. Since $y\phi - \beta < 0$, the curve's slope is flatter (less negative) the larger is e . It follows that, if a particular high- e individual is the highest bidder for a plot of land, that land must be located at a high x value, and conversely for a low-skill individual. If their locations were reversed, the high-skill individual could outbid the low-skill person for his land and vice versa. The location pattern that must prevail in equilibrium thus matches the

¹⁰ As in the benchmark model, it can be shown that this surplus measure equals total consumption plus aggregate land rent plus aggregate locational benefits, as derived below.

social optimum, with skills and residential distance positively related and a type- e individual living at $x(e)$.

In order for this pattern to emerge, however, the individual with a given e must actually bid more for the land at $x(e)$ than anyone else. This requirement means that, holding x fixed at $x(e)$, the maximum of $r(x(e), e')$ must be reached at $e'=e$. Thus, $\partial r(x, e)/\partial e$ evaluated at $x=x(e)$ must equal zero, and differentiating Eq. (14), it follows that

$$y - (y\phi - \beta)x(e) - u'(e) = 0 \tag{15}$$

must hold. Eq. (15) is a differential equation involving the unknown function $u(e)$. Rewriting Eq. (15) as $u'(e)=y - (y\phi - \beta)x(e)=y - (y\phi - \beta)NG(e)$ and integrating yields

$$u(e) = ey - (y\phi - \beta)N \int_e^e G(v)dv + A, \tag{16}$$

where A is a constant.

The constant A is determined by the requirement that land rent at the edge of the city equals zero. Substituting Eq. (16) into Eq. (14), setting $x=N$ and $e=\bar{e}$ (the skill level of the edge resident), and equating Eq. (14) to zero yields a solution for A .¹¹ Substituting in Eq. (16) then gives

$$u(e) = ey - [\bar{e}(y\phi - \beta) + t]N + (y\phi - \beta)NH(e), \tag{17}$$

where

$$H(e) = \int_e^{\bar{e}} G(v)dv. \tag{18}$$

It is easily seen that $u(e)$ is an increasing and convex function, with the latter fact ensuring that the first-order condition in Eq. (15) yields a maximum.

3.3. Preferred t values

The analysis in Section 2 showed that, when consumers are homogeneous, their preferred t minimizes the common transport cost per mile, $ey\phi(t)+t$. How does the outcome differ in a heterogeneous city with absentee landowners? Differentiation of Eq. (17) shows that the preferred t of a consumer with skill level e satisfies

$$- [\bar{e} - H(e)]y\phi'(t) = 1, \tag{19}$$

with the LHS expression giving the individual demand function for transport quality (the Appendix shows that $\bar{e} - H(e) > 0$ holds). As noted earlier, the demand curve is downward sloping given $\phi'' > 0$, which indicates that preferences for t are single-peaked.

This demand function exhibits three key additional features. First, recalling that $\phi' < 0$, demand (as measured by the height of the demand curve at a given t) is increasing in e , with the skill derivative from Eq. (19) having the sign of $-H'(e)=G(e) > 0$ (see Eq. (18)). This fact in turn implies that a consumer's preferred t is increasing in e . Second, demand is a strictly convex function of e , with the second derivative from Eq. (19) having the sign of

¹¹ The solution is $A = -[\bar{e}(y\phi - \beta) + t]N + (y\phi - \beta)N \int_e^{\bar{e}} G(v)dv$.

$G'(e)=g(e)>0$. This conclusion, which plays a key role in the ensuing analysis, is a consequence of the pattern of location by skill type. In other words, because high-skill workers have longer commutes in addition to having higher time costs for a given commute distance, the demand for transport quality increases at an increasing rate as the skill level rises.

The third key feature of demand comes from the fact that, for $e<\bar{e}$, the expression $\bar{e}-H(e)$ in the demand function in Eq. (19) exceeds e , which is established in the Appendix. The LHS of Eq. (19) is then larger than the LHS expression in the equality $-ey\phi'(t)=1$, which the consumer would satisfy in seeking to minimize his own transport cost. This comparison yields

Proposition 2. *The preferred transport system of an interior resident in a heterogeneous city has a higher t than the one that minimizes his own transport cost.*

The source of this result lies in the operation of the land market. To understand this point, note first that the land-rent function for the city is the convex upper envelope of the continuum of linear land-rent curves of the various residents, as should be clear from the derivation above.¹² The land rent paid by a resident living at location $x'<N$ then depends on the average slope of this convex envelope curve as it rises away from zero at the city's edge, approaching his interior residential location. A steep average slope, resulting from steep individual slopes for the underlying linear curves of the residents living outside x' , yields a high land rent for the x resident. But the steepness of these individual curves depends positively on the outer residents' transport costs, which are in turn determined by t (recall that the land-rent slope equals $-[e(y\phi(t)-\beta)+t]$ for a type- e individual). To moderate the land rent that he pays, the x resident would thus like to limit these outer costs, while still paying attention to his own transport cost. But, given their higher es , the outer residents have cost-minimizing ts higher than that of the x' resident. Therefore, with an eye on the outer costs, the x' resident prefers a t larger than the one that minimizes his own transport cost.

Note that this logic does not apply to the city's edge resident, who has no one living outside him. The edge resident's preferred t should thus reflect only his own income, a conclusion that can be verified in Eq. (19) by noting that $H(\bar{e})=0$. Note also that the "wedge" between ey and the corresponding term in Eq. (19) rises as e falls, reflecting the fact that low- e residents (who live near the center) have many outsiders whose transport costs affect the land rent they pay.

3.4. Comparing the voting equilibrium to the social optimum

As noted above, an individual's preferred t rises with his skill level. Thus, consumers have divergent interests in the choice of the transport system, which must be resolved through a majority-voting process.

¹² To establish the convexity of land rent, note that equilibrium rent as a function of x is given by $r(x, e(x))$ using Eq. (14), where $e(x)$ is the inverse function of $x(e)$. The derivative of r with respect to x then equals $\partial r/\partial x+(\partial r/\partial e)e'(x)$. Since the second term is zero from above, this derivative reduces to the first term, which equals $-(e(x)(y\phi-\beta)+t)$. Thus, land rent's second derivative with respect to x equals $-e'(x)(y\phi-\beta)>0$, where the inequality follows from $e'(x)>0$. Land rent is therefore a convex function of x .

As is well known, voting equilibria with heterogeneous consumers need not yield a socially optimal outcome, and the goal of the ensuing analysis is to investigate this potential for inefficiency in the present model. The first step is to identify the median voter. Since a consumer’s preferred t rises with e , the median voter is the individual with the median skill level, denoted \hat{e} . The median voter’s preferred t , denoted \hat{t} , thus satisfies

$$-[\bar{e} - H(\hat{e})]y\phi'(t) = 1. \tag{20}$$

To evaluate the optimality of the voting equilibrium, the \hat{t} given by Eq. (20) must be compared to the socially optimal value t^* , which satisfies $-2Jy\phi'(t)=1$ from Eq. (13). This comparison is eased by writing the social optimality condition in a different form, using the fact (established below) that social surplus and the total utility of urban residents are both maximized at the same value of t , just as in the homogeneous model. Thus, the heterogeneous social optimum maximizes $N [e_m y - (\bar{e}(y\phi - \beta) + t)N + (y\phi - \beta)N \int_{\underline{e}}^{\bar{e}} H(e)g(e)de]$ using Eq. (17) (recall that e_m is the mean skill level). The first-order condition for choice of t^* can then be written

$$-\left[\bar{e} - \int_{\underline{e}}^{\bar{e}} H(e)g(e)de \right] y\phi'(t) = 1, \tag{21}$$

where the LHS expression represents an alternate representation of the social demand for transport quality. Because the term multiplying $y\phi'(t)$ equals $-2J$, as shown in the Appendix, Eq. (21) is the same as the social optimality condition, $-2Jy\phi'(t)=1$.

The key to comparing \hat{t} and t^* is to recognize that the social demand curve from Eq. (21) is in fact the city’s *mean* demand for transport quality. This conclusion follows because the term multiplying $y\phi'(t)$ in Eq. (21) equals the average across the skill distribution of the corresponding terms in the individual demand functions from Eq. (19). Next, recalling that demand is strictly convex in the skill level, it follows from Jensen’s inequality that the demand of the city’s *mean voter*, given by $-\left[\bar{e} - H(e_m)\right]y\phi'(t)$, is less than the mean demand. In other words, strict convexity of $\bar{e} - H(e)$ yields $\bar{e} - H(e_m) < \bar{e} - \int_{\underline{e}}^{\bar{e}} H(e)g(e)de$, which implies that the mean voter’s demand curve is lower than the city’s mean (or social) demand curve for transport quality, as shown in Fig. 1.

Given this relationship, suppose that the median skill level is less than or equal to the mean, with $\hat{e} \leq e_m$ holding. With demand increasing in e , it then follows that the median voter’s demand curve lies below (or coincides with) the mean voter’s curve, as shown in Fig. 1. With the mean voter’s curve in turn lower than the social curve, the implication is that \hat{t} , the median voter’s preferred t , is less than the socially optimal value t^* . Summarizing yields

Proposition 3. *If the median \hat{e} of the city’s skill distribution is less than or equal to the mean e_m , then the voting equilibrium in the absentee-landowner case yields a value of t smaller than the socially optimal value. Thus, the city’s chosen transport system is less expensive and slower than the socially optimal one.*

The intuition behind Proposition 3 is simple. Convexity of demand, which reflects the longer commutes of higher-skill workers, means that the median voter’s demand curve

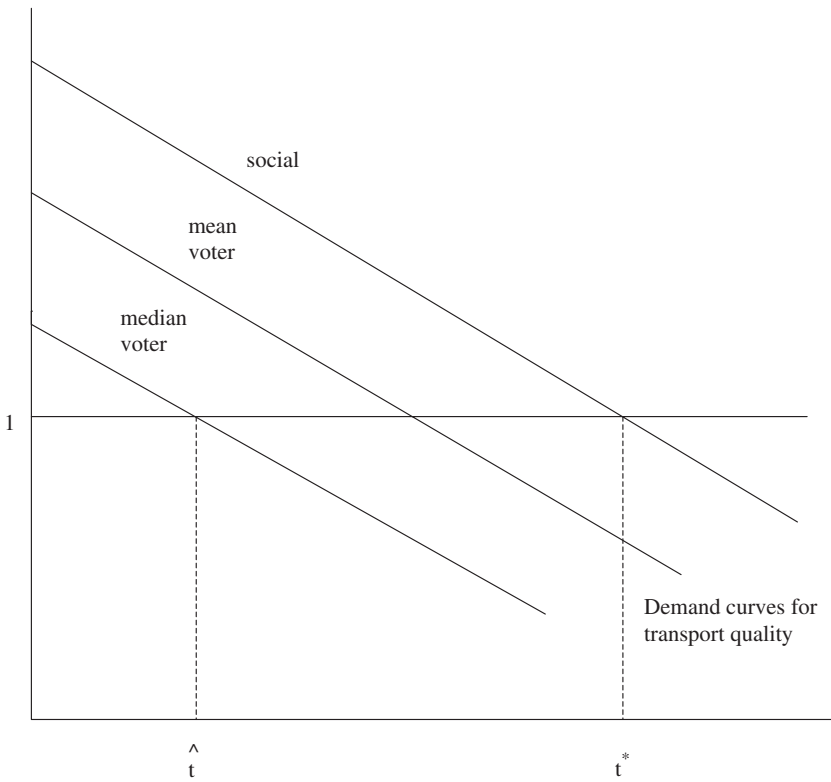


Fig. 1. Social optimum and voting equilibrium.

tends to understate society’s demand for transport quality, a tendency that is assured when $\hat{e} \leq e_m$. This understatement in turn leads the chosen t to be too small.

If $\hat{e} > e_m$ holds instead, implying that the skill distribution is skewed in the direction of low skills, then the comparison between \hat{t} and t^* is ambiguous. The reason is that, when $\hat{e} > e_m$, the median demand curve in Fig. 1 lies above the mean voter’s curve. As a result, the median curve could lie above or below the social demand curve, precluding a comparison of t values. However, if \hat{e} does not lie too far above e_m (if the skill distribution is not too strongly skewed toward low skills), then the underinvestment result of Proposition 3 continues to hold.

By showing that $\hat{t} < t^*$ holds when $\hat{e} \leq e_m$ and that the inequality may also hold in cases where $\hat{e} > e_m$, the analysis effectively identifies a bias toward underinvestment in transport quality. While this conclusion is reached without considering evidence on the nature of actual skill distributions, the underinvestment conclusion is strengthened once such evidence is brought to bear. In particular, since realistic skill and income distributions are strongly skewed in the direction of high skills, with median values lying well below means, the case where $\hat{e} < e_m$ and underinvestment occurs is the empirically relevant one. Interestingly, this conclusion contradicts the allegations of critics who claim that the US has overinvested in freeways at the expense of public

transit. Of course, since the model is highly stylized, this contradictory conclusion must be viewed as merely suggestive. But the conclusion shows that a simple economic model can generate insights into this important public policy question.¹³

The underinvestment bias that emerges from the model depends crucially on the pattern of location by skill type. To understand this conclusion, suppose that locational benefits do not offset the time cost of transport, so that $y\phi - \beta$ is positive instead of negative. This case would arise, for example, if locational benefits were absent, with $\beta=0$. Then, the skill pattern is reversed, with high-skill consumers living near the CBD and low-skill individuals living in the suburbs. Moreover, in this situation, it can be shown that the demand for transport quality is *concave* instead of convex in e , with the decline in commute distance causing demand to increase at a decreasing, rather than increasing, rate as e rises. But with concave demand, the mean voter’s demand curve lies above, rather than below, the social demand curve in Fig. 1. To see the nature of the resulting investment bias, suppose that $\hat{e} \geq e_m$ holds, so that the median demand curve lies above the mean demand. Then, since the mean demand lies above the social demand, the result is transport overinvestment, with $\hat{t} > t^*$. Since the same conclusion holds when $\hat{e} < e_m$ provided that the skill distribution is not too strongly skewed in the direction of high skills, the result is a bias toward *overinvestment*, rather than underinvestment, in transport quality.¹⁴ However, in contrast to the present analysis, the ambiguous case, where $\hat{e} < e_m$, is the realistic one, where skewness is toward high skills. Thus, while the model unambiguously predicts underinvestment in transport quality for the US case, it yields an ambiguous prediction for cities in Europe and elsewhere, where residential distance and income are often inversely related.

3.5. The effect of resident landownership

The next step in the analysis is to investigate how introduction of resident landownership affects the previous results. Accordingly, suppose that a type- e individual owns an exogenous share $s(e) < 1$ of the city’s land area, with $N \int_{\underline{e}}^{\bar{e}} s(e)g(e)de = 1$. It is easily shown that, with resident landownership, the only change in the model is the addition of rental income, given by $s(e)R$, to the utility expression in Eq. (17). As before, R is equal to aggregate transport cost net of locational benefits, which is represented by the second term in the surplus expression Eq. (12). Thus,

$$R = [2J(y\phi(t) - \beta) + t]N^2/2. \tag{22}$$

¹³ It is interesting to contrast Propositions 2 and 3. Even though Proposition 2 seems to point to the choice of a large \hat{t} , a value lying above the one that minimizes the median voter’s own transport cost, Proposition 3 shows that the chosen \hat{t} is in fact small enough to fall short of the value that minimizes total transport cost (assuming that $\hat{e} \leq e_m$ holds).

¹⁴ When β is small enough that the location pattern by skill is reversed, $x(e)$ in Eq. (10) is replaced by $N[1 - G(e)]$, J is replaced by $\int_{\underline{e}}^{\bar{e}} eg(e)[1 - G(e)]de$, $u(e)$ in Eq. (17) is replaced by $ey - [e(y\phi - \beta) + t]N + y\phi NH(e)$, where $H(e)$ is now $\int_{\underline{e}}^e G(v)dv$. The demand for transport quality is then $-[e - H(e)]y\phi'$, which is concave in e .

Since consumption from Eq. (17) is a concave function of t while R in Eq. (22) is convex, the curvature of the consumption expression that includes $s(e)R$ is ambiguous. However, provided $s(e)$ is small for all e , a natural assumption, the concavity of Eq. (17) will dominate, making the new consumption expression a strictly concave function of t . The first-order condition for choice of t then identifies the preferred value for a type- e individual, and it is given by

$$- [\bar{e} - H(e)]y\phi'(t) + s(e)(2Jy\phi'(t) + 1)(N/2) = 1, \tag{23}$$

where the first expression is the previous demand for transport quality and the second expression is proportional to the derivative of rental income with respect to t .

If $s'(e)=0$, so that the urban residents own equal shares of the city's land, then differentiation of Eq. (23) shows that the preferred t rises with e , implying that the median voter has $e=\hat{e}$, as before. However, for any other pattern of landownership, the identity of the new median voter is ambiguous.

Even with an arbitrary ownership pattern, useful information can be inferred from Eq. (23), as follows. Consider an individual whose preferred t in the absentee-landowner model was above t^* . Recognizing that the second expression in Eq. (23) is positive above t^* (see Eq. (13)), it follows that, when the LHS of Eq. (23) is evaluated at the individual's old preferred t , where the first term equals unity (see Eq. (19)), the expression exceeds one. As a result, each individual whose preferred t exceeded t^* under absentee landownership prefers a larger t under resident landownership. Conversely, each individual whose preferred t lay below t^* in the absentee case now prefers a smaller t . Summarizing yields

Proposition 4. *Resident landownership increases the dispersion around t^* of consumers' preferred t values, relative to the absentee case.*

Recognizing that rental income, which now accrues to consumers, rises as t moves away in either direction from the social optimum, the proposition makes intuitive sense. Each consumer's incentive to increase rental income pushes his preferred t away from t^* .

To develop the implications of this conclusion, let \check{t} denote the median preferred t under resident landownership, which is the level chosen in the resulting voting equilibrium. Then Proposition 4 yields

Corollary. *If $\hat{t} < t^*$, then \check{t} satisfies $\check{t} < \hat{t} < t^*$. If $\hat{t} > t^*$ holds, on the other hand, then $t^* < \hat{t} < \check{t}$.*

This result implies that, if the median preferred t falls short of (exceeds) t^* under absentee landownership, then the same conclusion holds under resident landownership. Moreover, resident landownership amplifies any difference between the voting equilibrium and the social optimum. To establish the first part of the corollary, suppose that $\hat{t} < t^*$. Then note that, since all the preferred t s lying below t^* fall in moving from absentee to resident landownership given Proposition 4, more than half of the population now has its preferred t below \hat{t} . As a result, the new median preferred t is smaller than \hat{t} and thus smaller than t^* . The same argument establishes the second part of the corollary.

Recalling from Proposition 3 that $\hat{t} < t^*$ holds when $\hat{e} \leq e_m$, and that $\check{t} < \hat{t} < t^*$ in this case, the following conclusion emerges:

Proposition 5. *If consumers are resident landowners and $\hat{e} \leq e_m$, then \check{t} is less than t^* . The chosen transport system under resident landownership is then slower and less expensive than the optimal one. Moreover, underinvestment in transport quality is more pronounced than under absentee landownership, with the chosen t lying farther below t^* than in the absentee case.*

As before, this conclusion is likely to hold when $\hat{e} > e_m$ provided that \hat{e} does not lie too far above e_m .

Proposition 5 shows that the conclusions of Proposition 3 continue to hold under resident landownership. Thus, regardless of landownership arrangements, a bias toward underinvestment in transport quality arises, with the chosen t falling short of t^* , unless the skill distribution is strongly skewed in the direction of low skills. In addition, Proposition 5 establishes that the impact of this underinvestment bias is more severe under resident landownership.

4. Building two transport systems

Consumers in the heterogeneous model have divergent interests, with the various skill types wanting different combinations of time and money cost in the transport system. By assuming that the city has just one system, the analysis has ruled out a possible means of addressing this diversity: construction of multiple transport systems. Several systems do indeed coexist in most cities, with extensive public transit systems often complementing freeway networks. As a result, it is of interest to investigate the system-choice problem when multiple transport systems are allowed.

The fixed cost of the transport system was suppressed in the preceding analysis, a permissible step under the assumption that any fixed costs are independent of t and ϕ . However, when multiple transport systems are allowed, consideration of fixed costs is crucial. The key question is then whether a better tailoring of system characteristics to consumer preferences, made possible by construction of multiple transport systems, is worth the additional fixed costs involved.

To investigate this trade-off, suppose that construction of any transport system requires a fixed cost of k per mile. The single transport system in the previous model, which extends to the edge of the city, thus requires a fixed cost of kN , which was ignored above. Note that a more realistic approach would recognize that k depends on the nature of the transport system and hence on t , but such a dependence would introduce unwelcome complexity. Since the ensuing analysis is only meant to be illustrative, this simplification, along with the others embedded in the model, is warranted.

Now suppose that the city contemplates building two transport systems. One system serves the high-skill individuals living in the outer part of the city, and as a result, it must extend from the CBD all the way to the city's edge, at a cost of kN . The other system serves the city's low-skill residents, and it extends from the CBD to some intermediate distance \bar{x} , at a cost of $k\bar{x}$. The analysis takes the perspective of a planner, asking what

configuration of transport systems is socially optimal. Possible equilibrium outcomes are briefly considered below.¹⁵

The planner’s goal is to minimize aggregate transport cost. To write the appropriate cost expression, let $e(x)$ denote the skill level of the individuals living at x . This function is the inverse of $x(e)$ in Eq. (10), being given by $e(x) \equiv G^{-1}(x/N)$. Letting the two transport systems be denoted by 0 and 1, aggregate transport cost equals

$$\int_0^{\tilde{x}} (e(x)y\phi(t_0) + t_0)xdx + \int_{\tilde{x}}^N (e(x)y\phi(t_1) + t_1)xdx + k\tilde{x} + kN. \tag{24}$$

The first-order conditions for t_0 and t_1 are

$$\int_0^{\tilde{x}} (e(x)y\phi'(t_0) + 1)xdx = 0 \tag{25}$$

$$\int_{\tilde{x}}^N (e(x)y\phi'(t_1) + 1)xdx = 0, \tag{26}$$

which can be reduced to a form analogous to Eq. (13) with suitable manipulation. Given $e'(x) > 0$, it can be shown using Eqs. (25) and (26) that $t_1 > t_0$ must hold at the optimum.¹⁶ Therefore, the transport system extending to the city’s edge is a costly, fast system while the one in the center is cheaper and slower, mirroring the pattern in US cities.

The first-order condition for choice of \tilde{x} is

$$(e(\tilde{x})y\phi(t_0) + t_0)\tilde{x} - (e(\tilde{x})y\phi(t_1) + t_1)\tilde{x} + k = 0. \tag{27}$$

This condition states that \tilde{x} is optimal when the saving in transport cost from switching the individual at \tilde{x} to system 0 from system 1 equals the cost k of the required marginal extension of system 0.

Insight into the nature of the solution to this choice problem comes from noting that the LHS of Eq. (27) is positive at $\tilde{x}=0$, being equal to k . Therefore, as system 0 is initially extended away from the CBD, aggregate transport cost rises. If construction of system 0 is ever to be optimal, aggregate cost must eventually start to fall with further extension of the system, ultimately dropping below the cost level at $\tilde{x}=0$ (where only system 1 exists). Therefore, system 0 must be extended an appreciable distance in order for its construction to be desirable.

Given this feature of the objective function for the system-choice problem, generation of additional insights must rely on simulation analysis. Accordingly, suppose that $\phi(t) = t^{-2}$, that skills are uniformly distributed, with $\underline{e} = 1$ and $\bar{e} = 5$, and that $y = 10$, $k = 0.1$, and $N = 1$. Using these assumptions, Eqs. (25) and (26) are solved for t_0 and t_1 as functions of \tilde{x} , and the results are substituted into the aggregate transport cost expression in Eq. (24). The graph of the resulting expression, which is a function of \tilde{x} , is shown in Fig. 2. As can be seen, construction of system 0 is not warranted under the given parameter values, with transport costs rising monotonically as \tilde{x} increases.

¹⁵ Note that commute trips are made on a single transport system, without switching from one to the other.

¹⁶ To establish this point, note that since $e'(x) > 0$, the terms $e(x)y\phi'(t_i) + 1$ are decreasing in x for $i = 0, 1$ (recall $\phi < 0$). As a result, for Eqs. (25) and (26) to hold, $e(\tilde{x})y\phi'(t_1) + 1 > 0$ and $e(\tilde{x})y\phi'(t_0) + 1 < 0$ must be satisfied. Since $\phi'' > 0$, these inequalities require $t_1 > t_0$.

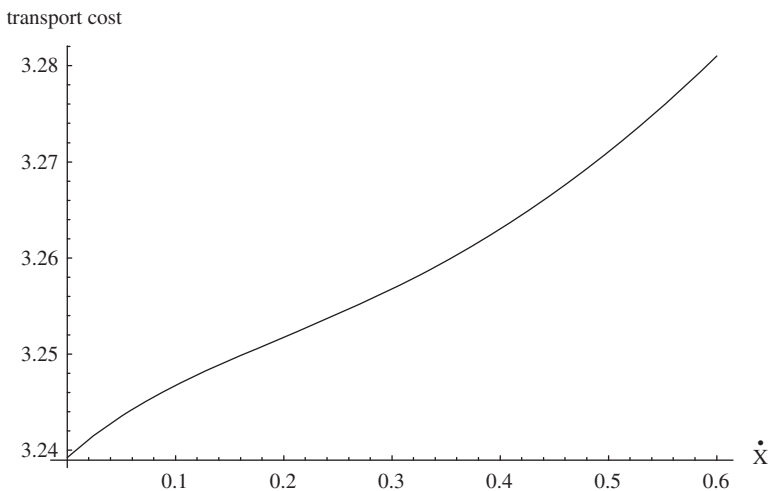


Fig. 2. High fixed cost and low skill dispersion.

Since divergence of consumer transport preferences provides the rationale for construction of a second system, an increase in this divergence may overturn the negative verdict of Fig. 2. This conjecture is confirmed in Fig. 3, which shows aggregate transport cost when \bar{e} is raised from 5 to 15. As can be seen, construction of system 0 is now desirable, with its optimal length being 0.30 (the system thus extends over 30% of the city). Since $t_1/t_0=1.43$, system 1 has a money cost 43% greater than that of system 0. However, the system is more than twice as fast, with $\phi(t_1)^{-1}/\phi(t_0)^{-1}=2.04$.

A reduction in fixed cost can also overturn the verdict of Fig. 2. When \bar{e} is set at its original value of 5 but k is reduced from 0.1 to 0.04, construction of system 0 is again

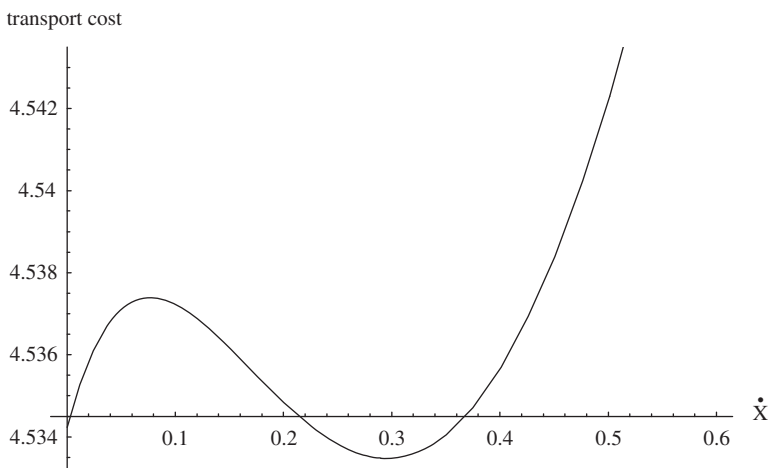


Fig. 3. High fixed cost and high skill dispersion.

optimal, as can be seen from a figure that looks very similar to Fig. 3. The optimal \tilde{x} equals 0.34, $t_1/t_0=1.27$, and system 1 is 62% faster than system 0.

While these results demonstrate the potential desirability of multiple transport systems, it is interesting to consider some equilibrium issues, including mode choice. One observation is that, in order to support the optimum, the marginal user of system 0 must pay a user fee of k , which makes him indifferent between the transport systems. Without such a payment, consumers will not split between the systems in the manner intended by the planner.¹⁷

5. Conclusion

This paper has analyzed the political economy of transport-system choice, with the goal of gaining an understanding of the forces involved in this important urban public policy decision. The analysis shows that, when the city is homogeneous, the chosen transport system is socially optimal regardless of landownership arrangements. This equivalence disappears, however, in a skill-heterogeneous city, with the chosen transport system being less expensive and slower than the optimal system under realistic skill distributions. This underinvestment, which is more pronounced under resident landownership, contradicts the allegations of critics who argue that the US has invested too much in fast, expensive freeways and too little in public transit. However, the model omits transport subsidies, which encourage investment in expensive systems, and adding this institutional feature could reverse the tendency toward transport underinvestment. Indeed, one implication of the analysis is that, because of this stimulative effect, such subsidies may be warranted.

Since the models analyzed in the paper are highly stylized, the conclusions reached are at best suggestive. However, the analysis provides a starting point for more realistic treatments of the transport-choice problem. One improvement would be to generate suburban location of high-skill consumers through endogenous land consumption rather than a taste for location, as is done in the present analysis. While the paper's continuum model becomes intractable under this modification, Brueckner (in press) is able to analyze a model with two income groups under the assumption of Leontief preferences. Further work in this direction (perhaps numerical in nature) would be useful.

¹⁷ The user-fee scheme required to support the optimum is not straightforward. To induce consumers to split properly across the two systems, it is easy to see that each consumer must pay for system 1 regardless of which transport system is used. An individual fee of k paid by each of the city's N residents would cover system 1's fixed costs. A scheme that charges k to each of the \tilde{x} users of system 0 would similarly cover its costs. But in order to ensure that all consumers living inside \tilde{x} use system 0, as intended, individuals living close to the CBD must pay a fee less than k . To see this point, replace \tilde{x} on the LHS of Eq. (27) by x , and note that this expression must be negative in order for an individual living at the given x to use system 0, assuming a user fee of k . Then, note that the slopes of the curves in Figs. 2 and 3 equal the LHS of Eq. (27), and that these slopes are positive for small values of \tilde{x} (and thus small values of x). The implication is that if consumers living near the CBD were charged a user fee of k , the LHS of Eq. (27) would be positive at their locations, indicating a preference for system 1. Thus, the user fee must be reduced for these consumers, and to cover costs, it must be raised above k at those x values where Eq. (27) is negative. On the other hand, a different fee scheme for system 0 would charge a user living at x an amount kx/\tilde{x} . This scheme ensures that the marginal individual pays k , and it can be shown that it induces the choice of system 0 by all residents inside \tilde{x} , as desired. However, since the scheme does not raise enough revenue, covering only half of system 0's cost, the balance would have to come from general tax revenue.

Another improvement would involve relaxation of the model's fixed-leisure assumption, allowing time costs to be generated as a byproduct of an endogenous labor–leisure choice. It can be shown that, when consumers have Cobb–Douglas preferences over consumption and leisure, some of the initial steps of the analysis are unaffected, but none of the major results can be derived.¹⁸

Finally, relaxation of the assumption of constant returns in the CBD production process creates a new stakeholder group: firm owners. While profits were previously zero, profits under decreasing returns are positive and increasing in total labor supply. As a result, firm owners (who were previously indifferent to the magnitude of t) now benefit from the fastest possible transport system, which delivers the largest labor supply to the CBD. In addition, knowing that a slower, cheaper system raises the wage by depressing CBD labor supply, consumers now prefer a smaller t than before. These effects are straightforward to analyze in the homogeneous model.

Further work on such extensions of the model would be useful. Generally, any additional research that provides insight into the important and understudied problem of transport-system choice would be worthwhile.

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Appendix A

To establish $\bar{e} - H(e) > e$, integration by parts is used to write $H(e)$ as

$$\bar{e} - G(e)e - \int_e^{\bar{e}} vg(v)dv. \quad (\text{a1})$$

Substituting Eq. (a1), $\bar{e} - H(e) - e$ equals $\int_e^{\bar{e}} (v - e)g(v)dv > 0$. Note that this result also establishes $\bar{e} - H(e) > 0$.

¹⁸ Explicit congestion is also missing from the model. However, given the assumption of fixed land consumption, traffic volumes (and hence the potential for congestion) are exogenous at each location. The realized level of congestion will depend, however, on the nature of the transport system, but this effect can be viewed as being already incorporated in the ϕ function. In other words, the faster travel that results from transport investment can be viewed as partly due to reduced congestion. In this way, the model can be interpreted as implicitly incorporating the congestion phenomenon. This interpretation is less tenable, however, in the two-system model of Section 4 given that splitting traffic across two systems is likely to reduce congestion on each relative to the case where just a single system exists.

Equality of the bracketed term in Eq. (21) and $2J$ requires

$$\bar{e} - \int_{\underline{e}}^{\bar{e}} H(e)g(e)de = 2J = 2 \int_{\underline{e}}^{\bar{e}} eg(e)G(e)de. \quad (\text{a2})$$

Integrating by parts to simplify the integral on the RHS of Eq. (a2) yields

$$2 \int_{\underline{e}}^{\bar{e}} eg(e)G(e)de = \bar{e} - \int_{\underline{e}}^{\bar{e}} G(e)^2de. \quad (\text{a3})$$

As a result, Eq. (a2) requires

$$\int_{\underline{e}}^{\bar{e}} H(e)g(e)de = \int_{\underline{e}}^{\bar{e}} G(e)^2de. \quad (\text{a4})$$

Integrating the LHS of Eq. (a4) by parts establishes the equality.

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