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Public infrastructure investments, productivity and welfare in fixed geographic areas

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Abstract

Measures of the value of public investments are critical inputs into the policy process, and aggregate production and cost functions have become the dominant methods of evaluating these benefits. This paper examines the limitations of these approaches in light of applied production and spatial equilibrium theories. A spatial equilibrium model of an economy with nontraded, localized public goods like infrastructure is proposed, and a method for identifying the role of public capital in firm production and household preferences is derived. Empirical evidence from a sample of large US cities suggests that public capital provides significant marginal benefits. But the marginal productivity of public capital is low, and aggregate city willingness to pay for large increases in public capital is less than their cost. The paper concludes with a brief discussion of the political economy of urban infrastructure investment. © 2002 Federal Reserve Bank of New York. Published by Elsevier Science B.V. All rights reserved.

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1. The debate over infrastructure

While the value of public capital has been a subject of substantial controversy, recent research has primarily focused on only one component of infrastructure's effect — its productivity. But the nation's infrastructure investment has other dimensions as well, including the consumption value of public capital and its role in influencing the location of economic activity. This paper addresses these

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dimensions simultaneously by providing both a new method and a new data set for estimating infrastructure benefits. The key insight is that infrastructure's effect on firms and households is mediated through its effect on local equilibrium prices.

Public capital may influence social welfare in two ways. The first is through income. If infrastructure contributes positively to private productivity, then more infrastructure will raise incomes and increase welfare. Concern about the role of public investment policies in productivity growth has generated many recent studies attempting to explore the role of infrastructure in private production, particularly since Aschauer (1989)) used national time series data to estimate a very high marginal productivity for public capital.

While the productivity of public capital is certainly one component of its aggregate social value, many of the most prominent authors in the ongoing debate over infrastructure productivity have recognized that direct, non-pecuniary, household benefits are a second avenue by which infrastructure may affect welfare. Reliable results from productivity and household studies must be combined with cost information to answer the normative question of whether the nation would benefit by directing more of its resources to public investment. This paper explores the limitations in current approaches to estimating infrastructure's contribution to productivity and provides a new strategy for analyzing the value of public capital in both production and consumption. The alternative described here provides a theoretically consistent accounting of these benefits, and allows clearer insight into the normative issues involved in infrastructure decision making.

Like most other research in this area, the empirical analysis here treats public capital stocks as exogenously determined. The assumption of infrastructure exogeneity has been made in most recent infrastructure studies, and a secondary advantage of the approach outlined here is that it provides a natural link between private economic outcomes and an appropriate political economy model of local investment behavior (Haughwout and Inman, 2000).

The majority of current research into the productivity question estimates either production or cost functions at the aggregate (state) level.[1] The distinction between the aggregate production (APF) and aggregate cost function (ACF) approaches to the estimation of factor productivities is based on contrasting theories of what may be treated as exogenous to firms (Friedlander, 1990; Berndt, 1991). Advocates of aggregate production functions implicitly argue that productive inputs (employment, private capital stock, etc.) are exogenously determined, and firms make output decisions based on the availability of these factors. Under this hypothesis,

[1] See, for example, Holtz-Eakin (1994)), Garcia-Mila et al. (1996)) and Morrison and Schwartz (1996)). Recent work by Rudd (2000)) applies a method similar to that employed in this paper to cross-sectional data from the 1980 Census. Rudd estimates that the marginal productivity of public capital at the SMSA level (city and suburbs combined) ranges between 0.0 and 0.15, depending on the treatment of local taxes. We believe that the panel structure of our data set provides advantages over a single cross-section.

the question of infrastructure productivity becomes whether additions to public capital stocks increase the output that can be obtained from given input stocks. In practice, APF estimates depend on the assumption that disturbances in output will be uncorrelated with quantities of inputs available.

ACF authors, however, prefer the assumption that input *prices*, not quantities, are treated as exogenous by producers. Morrison and Schwartz (1996)) concur with Berndt (1991)) in suggesting that ACF estimates are thus free of endogenous variable bias that plagues production function estimation, an argument that has a long history in the applied production theory literature. In this literature, authors have emphasized that while input use is clearly endogenous to production decisions, input prices will, in a competitive economy, be exogenous to the decisions of any particular firm.[2] The ACF and APF approaches thus embody opposite assumptions about own-price factor supply elasticities. Perfectly inelastic factor supply schedules (quantities given) suggest the APF approach, while perfect elasticity (prices given) suggests that ACF is the appropriate theoretical framework.

But application of this logic to the aggregate behavior of regions like the US states raises new issues. There are two sets of reasons to be concerned about the effects of aggregation. First is the question of how the relationships among production aggregates can be interpreted. In a series of papers, Fisher (1968a,b, 1969)) studied the conditions for the existence of consistent relationships between aggregate and microeconomic functions and variables. The conditions under which an aggregate production function exists, for example, are found to be quite restrictive, and even such commonly used measures as aggregate capital and labor stocks and aggregate output will be meaningful only in very special circumstances. Fisher (1969)) acknowledged that contemporary national time series estimates of such aggregate production functions performed surprisingly well, generally providing output elasticity estimates for labor and private capital near their shares in total income. He attributes this success to the fact that relative input stocks and prices had not changed dramatically over the years for which data were available. But the stylized fact that relative input prices and quantities are stable over time at the national level does not necessarily imply that they will be consistent over time and regions *within the nation*. Indeed, there is substantial variation across the states in both input stocks (Morrison and Schwartz, 1996; Holtz-Eakin, 1992) and prices over the post-WWII period (Carlino and Mills, 1996). Aggregate production function estimates have been especially plagued by implausible estimates of the marginal productivities of private inputs (Berndt and Hannsson, 1991).

Additional to these problems with the interpretation of aggregate variables and relationships is a second, related, set of issues. While the hypothesis of price

[2]Both Diewert (1974) and McFadden (1978) contain useful surveys and original contributions. This point was originally made in the context of infrastructure productivity estimation by Friedlander (1990).

exogeneity may be appropriate for the analysis of individual competitive firms, it is a far less satisfactory description of regional behavior. Regions like the US states and ex ante defined metropolitan areas have complex factor markets in which both the pure price- and quantity-taking assumptions are likely to fail.

Since the geographic areas defined as regions (states or federally-defined metropolitan areas) are pre-determined, their land area represents a fixed factor with an endogenous price which varies over space. Meanwhile, private capital supply to small regions is perfectly elastic at a nationally-determined (exogenous) price, but labor supply is neither perfectly elastic nor inelastic, and both wages and labor supply are endogenous to regions. The compensating variations literature pioneered by Rosen (1979)) and Roback (1982)), and extended by Blomquist et al. (1988)) and Gyourko and Tracy (1991)) shows that when regions are profit and utility takers, the value of unpriced, nontraded regional traits like climate or infrastructure stock will be fully reflected in local factor prices. Ultimately, maintained hypotheses about what is exogenous to regions are crucial, as they determine whether factor prices, quantities, or neither can be treated as exogenous explanatory variables in regional analysis.

Neither of the dominant methods of analyzing infrastructure productivity controls for the possibility that regional factor prices reflect part of the value of public capital. But if households and firms are mobile across regions, then wages and land values will vary in response to infrastructure provision, and the ACF and APF approaches can not adequately estimate the marginal productivity of public capital, let alone its social value. Exploiting regional data to answer the nation's infrastructure questions requires an empirical method which utilizes plausibly exogenous variables to identify the dual roles of public capital in firm production technologies and household consumption. Spatial equilibrium theory provides such a method. Section 2 derives and motivates an alternative measure of infrastructure's social value based on spatial equilibrium, and comments on its implications for aggregate approaches. Section 3 provides estimates of the role of public infrastructure in production and consumption in a set of US cities and Section 4 interprets the results and concludes the paper.

2. Model

This section derives the spatial equilibrium model of infrastructure effects, and provides the theoretical background for the empirical estimates in the following section. The model features free mobility, and relocation behavior by firms and households play a central role in determining the equilibrium impacts of changes in public investment.

Following the compensating variations literature pioneered by Rosen (1979)) and Roback (1982)), assume that regions are profit rate and utility takers. Like the maintained hypotheses of the APF and ACF approaches, this is a polar case, but one which is more consistent with both the concept of spatial equilibrium and the high degree of mobility exhibited by residential and business activities in the US. In what follows, the geographic area over which a given investment produces benefits is referred to as the region, but the definition of region is an empirical matter that is discussed in Section 3. In particular, there is no a priori reason to suppose that the benefits of particular public works are contained within a particular municipality or even state.

Workers and firms compete for scarce sites across regions. Individual firms produce a composite output good using a production technology of the form $x_j = x\{G_j, n_j, m_j\}$, where x is firm production, G is infrastructure available, n is private employment, m is land used by firms, and j indexes regions.[3] To focus on main ideas, assume that the firm's technology exhibits constant returns across the private inputs n and m and that infrastructure is financed with aid from higher levels of government.[4] Local input demands per unit of output (referred to as $n_j^1(R_j, W_j, G_j)$ and $m_j^1(R_j, W_j, G_j)$) will depend on regional prices for land (R) and labor (W) and infrastructure stocks. The zero-profit equilibrium condition for a firm in the jth region is then:

$$c\{W_j, R_j, G_j\} = P_X \tag{1}$$

where $c\{\cdot\}$ is the firm's unit cost function and P_x is the nationally-determined price of the composite output good. The jth region's public capital stock is 'productive' to an individual firm if $\partial x/\partial G_j > 0$, or, equivalently, if $\partial c/\partial G_j < 0$.

A finding that infrastructure is productive in this sense could be important in models of economic growth. Aschauer (1989)), for example, argues that a decline in relative infrastructure spending was an important contributor to the US productivity growth slowdown that began in the 1970s, while Munnell (1990a,b, 1992)) endorses this position and suggests that infrastructure differentials help explain interregional productivity variations. But as noted above, infrastructure's contribution to productivity is only one component of its social value.

The empirical literature has treated infrastructure as a pure national (Aschauer, 1989), state (Holtz-Eakin, 1994; Morrison and Schwartz, 1996) or regional (Eberts, 1990) public good. The aggregate marginal productivity of infrastructure may then be calculated by summing the individual productivity benefits across firms, $\Sigma\, \partial x/\partial G_j$, where the summation is over all firms in the region. The ideal method of analysis of the aggregate role of infrastructure in production is thus to collect data on the affected set of individual firms, calculate the marginal

[3]The exclusion of private capital has no effect on the regional economic equilibrium, as long as it is freely mobile and its price is determined in national markets, as is assumed here. Haughwout and Inman (2000) explore a similar model with private capital.

[4]Violation of the constant private returns assumption complicates the analysis but does not weaken the argument against the aggregative approach. The 'free infrastructure' assumption is relaxed below.

productivity of infrastructure for each, and aggregate these individual productivities to reflect infrastructure's nature as a public good. In practice, sufficient data on the behavior of individual firms are unavailable, and researchers have turned to the analysis of aggregate outcomes. It is crucial to recognize, however, that the question of infrastructure's productivity is a question about its effects on the output of individual firms, not on aggregate output. Cross-sectional or panel data evidence that infrastructure is associated with higher aggregate output at the regional level does not necessarily mean that increasing infrastructure stocks will raise *national* output, since the increase in productivity may be entirely associated with relocations of productive factors from other regions (Haughwout, 1998).

The potential for mobility of productive inputs means that even when the productivity of public capital is the only question of interest, a model of household behavior is necessary if aggregate data are to be analyzed. Assume that individual households have well-behaved[5] utility functions of the form $u_j = u(x_j, l_j, G_j)$, where x and l are, respectively, the household's consumption of the composite good and land, and j again indexes locations. Households maximize utility subject to the constraint that their expenditures equal the wage income they earn by (inelastically) supplying one unit of labor in the local productive process. In a free-mobility equilibrium, the level of indirect utility achievable by a household is identical across locations, or $u_j(\cdot) = \bar{V}$, where $\bar{V}$ is the nationally determined equilibrium utility level. Thus, the household must receive an equilibrium wage (W_j) that, given local land price R_j and infrastructure stock G_j, enables it to achieve the utility level which it can attain elsewhere:[6]

$$W_j = e(R_j, G_j, P_X, \bar{V}). \tag{2}$$

Public capital G is directly valuable as a consumption good if and only if $\partial u/\partial G_j > 0$ or, equivalently, if $\partial e/\partial G_j < 0$.

Following Roback (1982)), firm and household equilibrium conditions (1) and (2) may be implicitly solved for equilibrium local prices W_j^* and R_j^*:

$$R_j^* = R(P_X, G_j, \bar{V}) \tag{3}$$

$$W_j^* = W(P_X, G_j, \bar{V}) \tag{4}$$

Since both P_X and $\bar{V}$ are exogenous to any small region, local prices will vary with

[5] Twice-differentiable, quasi-concave.

[6] The household's (constant utility) wage bid function is an expenditure function, as the notation indicates.

local infrastructure stocks, the only unpriced, locationally fixed argument of either household or firm behavior (Roback, 1982).[7]

2.1. Aggregate output, employment and land use

Let $X_j^* = \Sigma x_j$, where the summation is over all firms in the region, represent aggregate output produced in region j. Under the assumption of constant returns over the private inputs at the firm level, expressions may be derived for aggregate employment, $N_j^* = n_j^1(\cdot)^* X_j^*$, land use by firms, $M_j^* = m_j^1(\cdot)^* X_j^*$ and land use by households $L_j^* = l_j(\cdot)^* N_j^* = l_j(\cdot)^* n_j^1(\cdot)^* X_j^*$. For the land market in region j to clear, its available land area $\bar{L}_j$ must be exhausted by firm and household demands. Thus, $M_j^* + L_j^* = (m_j^1 + l_j^* n_j^1)\, X_j^* = \bar{L}_j$, where, as above, m_j^1 and n_j^1 are firm demands for land and labor per unit output, l_j is demand for land by each household, and X_j^* is aggregate output produced in the region. Equilibrium aggregate output produced in region j is then given by:

$$X_j^* = \frac{\bar{L}_j}{(m_j^1 + l_j^* n_j^1)} = \frac{\bar{L}_j}{L_j^1(R_j^*, W_j^*, G_j)} \tag{5}$$

where $L_j^1 = m_j^1 + l_j^* n_j^1$ is the total land area utilized by firms and households in the production of each unit of output.

The assumption of fixed area is consistent with the analysis of states and other areas of fixed geography, like municipalities or metropolitan areas defined ex ante by the federal government. Of course, the appropriate geographic scale for the analysis infrastructure benefits is an empirical question. It is plausible that infrastructure generates costs and benefits that spill over political jurisdictions' boundaries and that regional definitions are themselves endogenous. Existing evidence suggests that infrastructure investments in a given state have little effect on neighboring states (Holtz-Eakin and Schwartz, 1995), but that they do induce intra-state effects. Boarnet (1998)) concludes that increases in a given California county's highway stock attract productive factors from other socio-economically similar counties in the state, while Haughwout (1997, 1999)) finds evidence that increases in central city infrastructure stocks induce land price increases in the surrounding suburbs. In the present context, these results suggest that measurement of the city effects of city investments provides a lower bound estimate of their aggregate benefits.

[7] In practice, of course, other non-traded public goods and amenities (like taxes and climate) will affect local prices. See, for example, Roback (1982), Blomquist et al. (1988), Gyourko and Tracy (1991). The current framework is general in that we can consider G_j a vector of non-traded regional attributes.

2.2. Comparative statics

Differentiation of (5) reveals the importance of local price adjustment in determining the effects of infrastructure on aggregate output:

$$\frac{dX_j^*}{dG_j} = \frac{-X_j^*}{L_j^1}\left[k_W \frac{dW_j^*}{dG_j} + k_R \frac{dR_j^*}{dG_j} + k_G\right] \tag{6}$$

where

$$k_W = \frac{\partial m_j^1}{\partial W_j^*} + l_j \frac{\partial n_j^1}{\partial W_j^*} + n_j^1 \frac{\partial l_j}{\partial W_j^*}, \qquad k_R = \frac{\partial m_j^1}{\partial R_j^*} + l_j \frac{\partial n_j^1}{\partial R_j^*} + n_j^1 \frac{\partial l_j}{\partial R_j^*}$$

and

$$k_G = \frac{\partial m_j^1}{\partial G_j} + l_j \frac{\partial n_j^1}{\partial G_j} + n_j^1 \frac{\partial l_j}{\partial G_j}$$

Comparative statics of the equilibrium prices may be obtained by total differentiation of (1) and (2). Note that since (1) defines a unit production cost function and (2) is a household expenditure function, Shephard's lemma allows us to write $\partial c/\partial R_j = m_j^1$; $\partial c/\partial W_j = n_j^1$ and $\partial e_j/\partial R_j = l_j$. Then:

$$\frac{dR_j^*}{dG_j} = \frac{-1}{L_j^1}\left[\frac{\partial c}{\partial G_j} + n_j^1 \frac{\partial e}{\partial G_j}\right] \tag{7}$$

and

$$\frac{dW_j^*}{dG_j} = \frac{1}{L_j^1}\left[m_j^1 \frac{\partial e}{\partial G_j} - l_j \frac{\partial c}{\partial G_j}\right] \tag{8}$$

Inspection of (7) and (8) provides insights into the equilibrium effects of public investment. When infrastructure is valuable to *both* households and firms, both $\partial c/\partial G_j$ and $\partial e/\partial G_j$ are negative. In these circumstances, $dR_j^*/dG_j > 0$, but equilibrium wages may rise or fall, depending on which sector (firms or households) benefits more from the investment. If infrastructure is productive but does not directly affect households, then $\partial c/\partial G_j < 0$, $\partial e/\partial G_j = 0$, and both land and labor price effects are positive.

But the sign of dX_j^*/dG_j is indeterminate, even when the public good plays a positive role in the production functions of every individual firm and households are indifferent to it.[8] A finding that $dX_j^*/dG_j > 0$ is *not* evidence that infrastructure is productive, i.e. it does not indicate that $\partial c/\partial G_j < 0$. The role of market prices in compensating firms and households for the value of unpriced elements of the environment makes it impossible for analyses of aggregate output and factor demands to uncover the role of infrastructure in either production or consumption.

Eqs. (5)–(8) indicate the difficulty of employing aggregate output data in the analysis of the productivity effects of infrastructure. New investments change the value and intensity of use of the fixed factor (land) and owners of that factor capture much of the benefit of the investment. Historical examples of this phenomenon abound, from the land price appreciation and residential activity that followed the construction of urban trolley lines in the 19th century (Jackson, 1985) to the development of shopping malls and office parks near suburban highway interchanges in the 1980s (Garreau, 1991).

Only empirical analysis of local price effects can reliably identify the equilibrium marginal productivity of public capital. It is to this task that we now turn, after brief examinations of how price effects can identify aggregate willingness to pay for infrastructure and its separate impacts on households as producers and consumers.

2.3. Identifying public capital's value to firms and households

In addition to providing a more theoretically consistent empirical model of infrastructure impacts, the compensating variations method allows both calculation of the aggregate willingness to pay for public capital investments and identification of the two avenues by which it affects welfare. To focus on main ideas, assume that the local tax system is non-distortionary, and that $\Omega_j(G_j, T_j)$ represents a public infrastructure investment plan, consisting of new public works G_j and the cost of providing them, T_j. Private actors' evaluations of Ω_j are expressed as their aggregate willingness to pay for the plan's adoption, ceteris paribus. Note that, in this general formulation, willingness to pay will be positive if the plan's aggregate local benefits exceed its aggregate cost to local residents, but if T_j includes funding from other levels of government then the local willingness to pay measure ought to be compared to total (not just local) costs in order to ensure efficiency. Firm willingness to pay for the plan is $-\partial c/\partial\Omega_j$ (equilibrium cost savings per unit

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[8] Substitution of (7) and (8) into (6) yields the following complex expression for the relationship between aggregate output and infrastructure provision:

$$\frac{dX_j^*}{dG_j} = \frac{X_j^*}{L_j^1}\left\{\frac{1}{L_j^1}\left[(k_W l_j + k_R)\frac{\partial c}{\partial G_j} + (k_R n_j^1 - k_W m_j^1)\frac{\partial e}{\partial G_j}\right] - k_G\right\}$$

There is no regular relationship between a productive public good (defined as a public good for which $\partial c/\partial G < 0$) and aggregate output X^*. See Haughwout (1998) for more detail and discussion.

output), while for households it is $-\partial e/\partial\Omega_j$ (equilibrium expenditure savings per household). Aggregate willingness to pay is then[9]:

$$\begin{aligned} WTP_j &= -X_j^* \frac{\partial c}{\partial \Omega_j} - N_j^* \frac{\partial e}{\partial \Omega_j} \\ &= -X_j^* \left\{ -\left(n_j^1 \frac{\mathrm{d}W_j^*}{\mathrm{d}\Omega_j} + m_j^1 \frac{\mathrm{d}R_j^*}{\mathrm{d}\Omega_j} \right) \right\} - N_j^* \left\{ \left(\frac{\mathrm{d}W_j^*}{\mathrm{d}\Omega_j} - l_j \frac{\mathrm{d}R_j^*}{\mathrm{d}\Omega_j} \right) \right. \\ &= (M_j^* + L_j^*) \frac{\mathrm{d}R_j^*}{\mathrm{d}\Omega_j} = \bar{L} \left. \frac{\mathrm{d}R_j^*}{\mathrm{d}\Omega_j} \right\} \end{aligned}$$

The question of whether there is 'enough' infrastructure from the local perspective is thus whether a program to raise and invest an additional dollar in infrastructure increases city aggregate land values. This rule, which is analogous to that derived by Brueckner (1979, 1982)) for the case of exogenous incomes, bears no consistent relationship to the test implicit (and sometimes explicit) in the APF and ACF literature, which is to invest until aggregate marginal product equals marginal social cost, including excess burden (Morrison and Schwartz, 1996).

In spite of the fact that the sign and size of $\mathrm{d}W_j^*/\mathrm{d}G_j$ are irrelevant to the efficiency of local public sector activity, its estimation serves a valuable purpose. With it, we can determine the incidence of infrastructure benefits across the two sectors. This is crucial, since $\mathrm{d}X_j^*/\mathrm{d}G_j > 0$ cannot be interpreted as evidence that public good G is productive. But the compensating variations method allows identification of the separate effects of infrastructure on firm productivity and household welfare. Rearrangement of (7) and (8) yields:

$$\frac{\partial c}{\partial G_j} = -\left(n_j^1 \frac{\mathrm{d}W_j^*}{\mathrm{d}G_j} + m_j^1 \frac{\mathrm{d}R_j^*}{\mathrm{d}G_j} \right) \tag{9}$$

and

$$\frac{\partial e}{\partial G_j} = \frac{\mathrm{d}W_j^*}{\mathrm{d}G_j} - l_j \frac{\mathrm{d}R_j^*}{\mathrm{d}G_j} \tag{10}$$

Under the assumption of free mobility, estimates of $\mathrm{d}W_j^*/\mathrm{d}G_j$ and $\mathrm{d}R_j^*/\mathrm{d}G_j$ can thus be combined with land use and employment data to separately identify household and firm willingness to pay for infrastructure (or other public services) located in a particular geographic area.[10]

[9] Roback (1982) obtains an identical result, but does not apply it to the analysis of public decision-making.

[10] Beeson and Eberts (1989) obtain a similar result.

3. Data, estimation and evidence on the effects of city infrastructure

Calculation of infrastructure's effects on regional prices requires an empirical design which can distinguish infrastructure effects from those generated by other produced and non-produced regional traits. The dependent variables for the estimation are central city house prices and wages from the *American Housing Survey* national files micro data, while the principal independent variables are constructed from US Bureau of the Census' *Government Finances* publication series. While the data set includes detailed information on houses and their residents that varies within cities in a given year, the fiscal information in a given year varies only across, not within, cities. A complete list of variables, the type of variation they provide and their sources appears in Table 1. Table 2 provides descriptive statistics for the key variables.

The public capital data differ in two key ways from those currently in widespread use. The replacement value of public capital in place is estimated by applying the perpetual inventory technique to gross-of-depreciation capital investment flows from 1905 to the present. Holtz-Eakin (1993)) and Munnell (1990a,b)) both provide state-level estimates of the replacement value of public capital in place by apportioning national aggregates to each state based on the state's share of national gross investment during a benchmark period. This procedure introduces the possibility of systematic measurement error into the public capital measure, since investments made during the benchmark period may be correlated with factors other than historical investment patterns. Because the current method requires no bench marking, it provides a measure of city and state public capital that is less likely to contain measurement error.[11] It does, on the other hand, require an assumption that no public capital in place as of the starting date survives to the present. Haughwout and Inman (1996)) contains a complete description of the public capital data and 1972–1992 values for the central cities analyzed here.

The infrastructure measure employed here requires data on the investments made by each government over a long historical period, and such data are available only for state governments and large cities. While the analysis is thus limited to the effects of infrastructure provision in the cities listed in Table 3, the addition of sub-state infrastructure variation into the analysis is valuable. Recent evidence, summarized above, suggests that infrastructure investments have effects on the intra-state location of economic activities. If this conclusion is correct, then the case for state-level analysis is considerably weakened. It also qualifies the interpretation of the empirical analysis performed here. If infrastructure is found to have a positive marginal benefit in these central cities, it does not follow that it has positive effects in the state (or nation) as a whole. Benefits realized in the city

[11] Garcia-Mila et al. (1996), using an aggregate production function model, test for and reject the hypothesis that the Munnell series is measured with error.

Table 1
Descriptions, level of variation and sources for key variables

Dependent variables: vary by house (i), region (j) and time (t).
Source: US Bureau of the Census, 1974–1991
1. *HV*, House and land value, continuous.
2. *W*, Annual wages and salaries, head of household, continuous.

HQ vector: house quality controls, vary by house (i), region (j) and time (t). Source:
Source: US Bureau of the Census, 1974–1991
1. No. of bathrooms: polychotomous, 1, 1.5, 2, 2.5+
2. No. of bedrooms: polychotomous, 1, 2, 3, 4, 5, 6+
3. Basement: dichotomous, 0–1
4. Condominium: dichotomous, 0–1
5. Central air conditioning: dichotomous, 0–1
6. Detached unit: dichotomous, 0–1
7. Garage present: dichotomous, 0–1
8. Age of house: continuous[a]
9. No. of other rooms: continuous (=total rooms − bedrooms − bathrooms)
10. Public sewerage hookup: dichotomous, 0–1
11. Heating equipment: polychotomous (warm air, electric, steam, other)
12. House quality rating: polychotomous (excellent, good, fair, poor)
13. Central city indicator: dichotomous, 0–1

HC vector: head of household human capital controls, vary by house (i), region (j), and time (t). US Bureau of the Census, 1974–1991
1. Age: continuous
2. Education: polychotomous (no school, elementary, some HS, HS graduate, some college College graduate, graduate school)
3. Married: dichotomous, 0–1
4. White: dichotomous, 0–1
5. Hispanic: dichotomous, 0–1

STS and **LTS**: local and state tax and service vectors, vary by region (j) and year (t).
Sources: *Government Finances* (GF) series (Census a, various years); *Significant Features of Fiscal Federalism* (ACIR, various years); US Bureau of the Census, 1974–1991; *Digest of Educational Statistics* (DES), (Department of Education, various years); *Uniform Crime Reports* (UCR), (FBI, various years).
1. Mean city effective property tax rate: continuous, Source: AHS
2. City income tax rate: continuous, ACIR
3. City sales tax rate: continuous, ACIR
4. Serious crimes per 100 000 population: continuous, UCR
5. Pupil–teacher ratio in city schools: continuous, DES
6. State income tax rate: continuous, ACIR
7. State sales tax rate: continuous, ACIR
8. City infrastructure stock: Continuous, GF and author's calculations (See Haughwout and Inman, 1996 for details)
9. State infrastructure stock: continuous, GF and author's calculations (See Haughwout and Inman, 1996 for details)

A: unproduced amenities, vary by region (j). Source: US Bureau of the Census (1989)) and author's calculations.
1. Coastal status: dichotomous, 0–1, author's calculations
2. Mean annual rainfall: continuous
3. Mean annual heating degree days: continuous
4. Mean cooling degree days: continuous

[a] Age of the house is computed as a function of when the house is reported to have been built. Those data are reported in interval form. The midpoint of the interval is used as the year of construction. When bottom coding is relevant (for old homes), the house is assumed to have been built during the bottom code year.

Table 2
Descriptive statistics for second stage variables

Variable	Mean	S.D.	Min	Max
$\hat{\alpha}_2$ (Land price effect)	10.39	0.37	9.43	11.79
$\hat{\beta}_2$ (Labor price effect)	7.25	0.20	6.12	7.98
Violent crime (per 100 000 pop)	1268.95	596.31	385.15	4041.08
Pupil–teacher ratio	20.12	2.63	12.60	27.40
Property tax rate (%)	1.33	0.66	0.21	3.51
State income tax rate (%)	5.33	3.94	0.00	16.00
State sales tax rate (%)	4.30	1.17	0.00	6.50
Local sales tax rate (%)	1.15	1.09	0.00	5.00
Coastal dummy	0.27	0.44	0.00	1.00
Mean rainfall (inches per year)	34.37	11.74	7.66	61.88
Heating degree days	4400.25	2040.39	137.00	7981.00
Cooling degree days	1294.69	947.09	65.00	4162.00
State infrastructure stock (billions of $1990)	40.68	23.17	8.19	89.36
City infrastructure stock (billions of $1990)	6.29	4.64	1.77	23.42
City infrastructure stock per capita (thousands of $1990)	8.67	3.45	1.86	19.80
City long term debt outstanding (billions of $1990)	0.81	0.93	0.03	6.87
City long term debt per capita (thousands of $1990)	1.02	0.85	0.08	6.33
City land area (sq miles)	192.3	153.8	40.6	666.2
City population	813 936	683 041	331 163	3 487 390

jurisdiction may come at the expense of distant parts of the state (as in Boarnet, 1998), and/or may spill over to spatially proximate jurisdictions (Haughwout, 1997, 1999).

The data set combines micro-data on housing and workers with city-level amenities and fiscal information. In order to ease interpretation, a two-stage estimation procedure is performed to determine whether city infrastructure can account for the any of the variance in land prices and wages across cities over time (Card and Krueger, 1992; Hanushek et al., 1996).[12] In the first stage, city–year effects in land prices and wages are computed. Determining them requires estimation of land price and wage equations:

$$\text{Log}\, HV_{i,j,t} = a_1 \boldsymbol{HQ}_{i,j,t} + a_2 \boldsymbol{C}_j \cdot \boldsymbol{T}_t + \epsilon_{i,j,t} \tag{11}$$

$$\text{Log}\, W_{i,j,t} = b_1 \boldsymbol{HC}_{i,j,t} + b_2 \boldsymbol{C}_j \cdot \boldsymbol{T}_t + \mu_{i,j,t} \tag{12}$$

[12] Combining the two steps outlined below into a single step results in no important changes in the results. Haughwout (1999) estimates a housing price equation in one step and gets results very similar to those reported below.

Table 3
Estimated city land price and wage effects

City		Years of data[a]	Mean $\hat{\alpha}_2$	Mean $\hat{\beta}_2$
1	Atlanta		10.39	7.08
2	Baltimore		10.36	7.27
3	Boston	1974–1979, 1983–1991	10.71	7.24
4	Buffalo	1974–1983	9.90	7.06
5	Chicago		10.47	7.29
6	Cincinnati		10.25	7.27
7	Cleveland		10.08	7.26
8	Columbus		10.22	7.31
9	Dallas		10.38	7.33
10	Denver		10.61	7.17
11	Detroit		9.91	7.36
12	Ft. Worth		10.16	7.27
13	Houston		10.36	7.27
14	Indianapolis		10.15	7.26
15	Kansas City, Missouri		10.11	7.21
16	Los Angeles		11.09	7.36
17	Memphis	1985–1991	10.16	7.23
18	Milwaukee		10.33	7.27
19	Minneapolis		10.53	7.22
20	New Orleans		10.51	7.34
21	Oakland	1985–1991	11.22	7.44
22	Oklahoma City		10.24	7.25
23	Omaha	1985–1991	10.03	7.07
24	Philadelphia		10.25	7.21
25	Phoenix		10.40	7.20
26	Pittsburgh		10.13	7.05
27	Portland, Oregon	1974–1983	10.44	7.21
28	San Antonio	1985–1991	10.17	6.88
29	San Diego		10.91	7.28
30	San Francisco		11.25	7.39
31	Seattle		10.66	7.31
32	St. Louis		10.13	7.36
33	Toledo		10.27	7.30

[a] 1974–1979, 1981, 1983, 1985, 1987, 1989, 1991 unless otherwise noted.

Here, i, j, and t, respectively, index individuals, cities and time, HV is house value, W is the household head's wage, $\boldsymbol{HQ}$ and $\boldsymbol{HC}$ are house quality and human capital controls, and boldface type indicates vectors. $\boldsymbol{C}_j$ and $\boldsymbol{T}_t$ are, respectively, city and time dummy variables; their interaction allows estimation of city–year specific fixed effects in house prices and wages. $\epsilon_{i,j,t}$ and $\mu_{i,j,t}$ are standard 'white noise' residual terms. These first-stage regressions are estimated with ordinary least squares over 10 166 housing units in 33 central cities in 12 cross sections. A list of the cities, the years they are present in the data set and their mean values for $\hat{\alpha}_2$ and $\hat{\beta}_2$ are provided in Table 3.

The second stage of the estimation strategy involves examining whether variance in local amenities (A_j), local or state current tax, service and public debt conditions ($LTS_{j,t}$ and $STS_{j,t}$), and public infrastructure stocks ($LG_{j,t}$ and $SG_{j,t}$) can account for the variance in the estimated city–year effects in local prices. The $\hat{\alpha}_2$ and $\hat{\beta}_2$ vectors (each a 355×1 column vector) from Eqs. (11) and (12) are regressed on the city-level variables:

$$\hat{\alpha}_{2,j,t} = g_1\boldsymbol{A}_j + g_2\boldsymbol{LTS}_{j,t} + g_3\boldsymbol{STS}_{j,t} + \gamma_4 LG_{j,t} + \gamma_5 SG_{j,t} + \nu_{j,t} \tag{13}$$

$$\hat{\beta}_{2,j,t} = d_1\boldsymbol{A}_j + d_2\boldsymbol{LTS}_{j,t} + d_3\boldsymbol{STS}_{j,t} + \delta_4 LG_{j,t} + \delta_5 SG_{j,t} + \eta_{j,t} \tag{14}$$

Since $\hat{\alpha}_2$ and $\hat{\beta}_2$ are estimates, $\nu_{j,t}$ and $\eta_{j,t}$ will be heteroscedastic, with variances depending on the sampling variances of the dependent variables. GLS is the appropriate estimator, with the inverse of $\hat{\alpha}_2$ and $\hat{\beta}_2$'s sampling variances as weights. Note that the key local price effect parameters (γ_4 and δ_4) are identified from the reduced form model represented in (3) and (4).

Hedonic pricing equations like (11) and (12) are often sensitive to specification. Of particular concern is the possibility that the city–year specific effects will be correlated with the second stage residuals $\epsilon_{i,j,t}$ and $\eta_{i,j,t}$. Two errors in the specification of (11) and (12) may cause this to occur. First, if the functional forms of (11) and (12) are incorrectly specified, then the resulting residuals may be hetereoscedastic, with variances proportional to $\hat{a}_2$ and $\hat{b}_2$. The result will be inefficient estimates of the second stage dependent variables. To control for mis-specification of the functional form, housing and worker traits are measured as sets of dummy variables, which allows for significant non-linearity on the right hand sides of (11) and (12). Estimation with the dependent variables measured in real dollars instead of natural logarithms has no effect on the important results, although the estimated payoffs to new investment are somewhat higher than those reported in Table 4.

A potentially more serious problem results if variables omitted from (11) and (12) vary systematically over cities and years. (Gyourko and Tracy, 1991 discuss a similar problem). Such variables would be those that affect the prices of individual properties (or wages of individual workers) without having market-level effects controlled for in the second stage; unobserved unit characteristics, perhaps a spectacular view, are the most likely candidates. If such characteristics affect individual property values and vary systematically across cities and years, then cities and years with valuable unobservables will have large values for $\hat{a}_2$. We tested for the importance of this problem by including resident income as an independent variable in (11). Since it seems a reasonable assumption that high quality workers demand high quality housing, and since unobserved traits of the sort that would bias $\hat{a}_2$ are observed by the resident, including resident income ought to help purge the residual of their effects. The results reported in Tables 3 and 4 are insensitive to the inclusion of income, indicating that missing variables

Table 4
Infrastructure returns and productivity[a]

Description	City and year fixed effects?	Land price per acre	Land price elasticity	Present value wages per worker	Wage elasticity	Aggregate willingness to pay ($ Millions)			CRTS output elasticity
						Firms	Households	Total	
1/Level	N	$14 639	0.15	$450	0.003	$673	$1157	$1831	0.027
		(1902)	(0.02)	(284)	(0.002)	(121)	(199)	(233)	(0.005)
2/Log	N	22 101	0.23	509	0.003	955	1808	2764	0.038
		(2872)	(0.02)	(364)	(0.002)	(164)	(289)	(332)	(0.006)
3/Level	Y	11 444	0.12	−2340	−0.016	−433	1864	1431	−0.017
		(3903)	(0.04)	(1283)	(0.009)	(477)	(577)	(749)	(0.019)
4/Log	Y	10 972	0.12	−2310	−0.016	−439	1811	1372	−0.017
		(1426)	(0.05)	(1304)	(0.009)	(467)	(482)	(671)	(0.018)

[a] Estimated city effects of a one standard deviation (4.64 billion $1990) increase in mean city's infrastructure stock. Note: standard errors in parentheses. Annual wage effects are treated as perpetuities, and discounted to present value terms assuming a discount rate of 6%.

in (11) and (12) do not seriously bias the dependent variables in (13) and (14). The inclusion of city and year fixed effects in the second stage regressions also help to control this potential source of bias.

The coefficients $\hat{\gamma}_4$ and $\hat{\delta}_4$ retrieved from estimation of (13) and (14) are the estimated land price and wage effects of central city infrastructure stocks, which are the basis of the willingness to pay calculations provided below.

3.1. City land area and city infrastructure specification

Two further estimation issues arise. First, standard urban economic models emphasize the importance of proximity to employment nodes in determining the market value of land, with centrally located properties commanding the highest locational premia (Fujita, 1989). In the present context, it is thus likely that physical size of the central city will have a ceteris paribus effect on the city-specific land price effect, since the sample of houses drawn from a geographically larger city will be more heavily weighted toward units that are relatively distant from the central business district or other employment nodes.[13] Addition of city land area to the second stage regressions controls for this element of the *AHS* sampling design.

A more substantive question that has received little attention in aggregate models is the congestibility of physical infrastructure. In the majority of recent APF and ACF studies, infrastructure is measured as the replacement value of the current stock and is treated as a pure, uncongestible public good. Of course, the true value of public capital is the services it provides, and the replacement value of the stock is a proxy for infrastructure services made necessary by lack of direct data on infrastructure services. One potential problem with this treatment is congestibility: for a given stock, the service flow may be (inversely) related to the population utilizing the facility. Here, we perform a grid search for the proper specification by substituting:

$$LG_{j,t} = f(STOCK_{j,t}) = \frac{STOCK_{j,t}}{POP_{j,t}^{\theta}}$$

where θ ranges from 0 (a pure public good specification) to 1 (pure private good) (Bergstrom and Goodman, 1973; Fernald, 1999, employs a similar strategy).

The grid search reveals that the effect of infrastructure on city land premia falls monotonically as θ rises. Measured as a pure private good ($\theta = 1$), infrastructure has an insignificantly negative effect on land values (and, as is the case for all other values of θ, no significant effect on wages). As θ is reduced, the infrastructure coefficient becomes significantly positive. These effects are driven

[13] It is also possible that city workers are compensated for long commutes with higher wages, although there is little evidence of this in the data.

by the presence of city population in the denominators of the infrastructure measures. When city population is included as a separate regressor, both its coefficient and the coefficient on infrastructure stock per capita (i.e. $\theta = 1$) become positive and significant. Under the compensating variations framework, city populations (like city employment) are endogenous, responding to city land and labor market conditions rather than the converse. These considerations, along with the fact that the specification with $\theta = 0$ describes the data best (i.e. it has the lowest mean squared error), confirm the treatment of central city infrastructure as uncongested. This may seem surprising until it is recognized that the majority of the central cities in the sample have lost population and employment since the 1960s. This suggests the potential for excess capacity in city infrastructure stocks, indicating that aggregate city returns to new investments may be low, a conclusion which foreshadows the results reported below.

3.2. Effects of city public capital on local factor prices

Table 4 reports the estimated city infrastructure elasticities retrieved from reduced-form estimation of Eqs. (13) and (14).[14] The specifications are distinguished by maintained hypotheses about the linearity of infrastructure's effects on factor prices and by the treatment of city and year fixed effects.[15] The figures in the table are the effects of a one standard deviation (4.64 billion 1990 dollars) increase in the replacement value of city-owned infrastructure in place.

Since the local (and state; see below) government budget constraints are not explicitly modeled here, the results must be interpreted carefully (Gyourko et al., 1999). Infrastructure stocks in place in a given year are a combination of remaining stock from previous years and new investment. The latter may be funded from current local revenues, by aid from higher levels of government, new debt or, most commonly, by some combination of these (Hulten and Schwab, 1997). The regression equations on which the Table 4 calculations are based include major local tax rates, outstanding long term debt per capita, and measures of public safety and education services, which are presumably related to spending. The Table 4 results are thus interpretable as the effect of increased infrastructure conditional on these variables remaining unchanged. The new infrastructure might thus be funded by aid from higher levels of government, high levels of past investment, or changes in excluded portions of the local budget. The finding of significantly positive coefficients thus indicates that city residents (and/or businesses) place a positive value on infrastructure that comes without changes in major taxes or the level of key public services. While this is perhaps unsurprising, the

[14] All annual effects are treated as perpetuities and converted to present values using a 6% discount rate.

[15] Decomposing the residual terms $\nu_{j,t}$ and $\eta_{j,t}$ into city- and year-specific random effects did not significantly change the conclusions reported here.

key policy question for federal, state and local officials is whether aggregate willingness to pay for such investments is as large as their cost.[16]

Since theory provides no guidance on the functional form of the relationships among public services and factor prices, both log-linear and semi-log specifications are estimated. The dependent variables are the (log) city–year land and labor price effects estimated in the first stage. The infrastructure stock variable is measured as either a level (specifications 1 and 3) or natural logarithm (specifications 2 and 4). Estimation is via GLS, with the inverse sampling variances of the estimated dependent variables as weights. City and year fixed effects, which are jointly significant at standard confidence levels, replace time-invariant local amenities in specifications 3 and 4.

In each specification, the replacement value of current infrastructure stocks has a precisely estimated positive association with land values, and the effects are economically significant as well. A one standard deviation increase in the typical city's infrastructure stock, conditional on taxes, debt, crime and pupil–teacher ratio, is estimated to raise the value of an acre of city land by amounts ranging from \$11 000 to \$22 000, or an elasticity range of 0.11–0.23. This finding reinforces the important message of this paper: metropolitan area factor markets capitalize the net benefits of untraded, publicly provided goods.

The connection between infrastructure and wages is less significant in both statistical and economic terms. In all models, the \$4.64 billion increase in infrastructure stocks is estimated to have relatively small effects on the present discounted value of wages, and in the fixed effects models, wage effects are estimated to be negative. In none of the specifications can the hypothesis of no wage effect be rejected with 95% confidence. Recall from Eq. (8) that infrastructure's equilibrium wage effects are a (weighted) difference between its value to firms and households. A finding of negative wage effects implies that household's willingness to accept lower wages for more infrastructure outweighs firms' willingness to pay higher wages. Estimates of household and firm willingness to pay for infrastructure are presented in the right hand panels of Table 4.[17] While city infrastructure provision provides statistically and economically significant benefits at the margin, the aggregate willingness to pay for a one standard deviation increase in city infrastructure is not, for the typical city,

[16]Alternatively, the full regression results could be used to calculate the ceteris paribus effect of increasing borrowing or tax rates in order to raise public investment funds. The total property value effect of such a program is then the sum of tax or debt effect and the infrastructure effect. Haughwout (1999) conducts such an experiment for property tax finance, and reports that increasing central city property taxes to finance new public works would return to city residents only about 60 cents on the dollar.

[17]These estimates use data from the *State of the Nation's Cities* data base (Center for Urban Policy Research, 1996). Firm use of land, which is an important input to the willingness to pay calculations reported in Table 4, is measured only at the metropolitan area level, and scaled back to central cities. Household land use data are taken from the 1993 *AHS*.

sufficient to offset its cost. The largest aggregate value estimate (line 2 of Table 4) is only about 60% of the $4.64 billion cost required to raise infrastructure stock in the typical city by a sample standard deviation. The marginal productivity of infrastructure is estimated to be non-negative, but small. Indeed, in lines 3 and 4 of Table 4, the hypothesis that aggregate firm benefits (and, of course, marginal productivity) are zero cannot be rejected, and the point estimates are negative. Household benefits, meanwhile, are consistently estimated to be positive and relatively large.

Taken together, these results imply that infrastructure is indeed valuable, if only when provided without changes in local tax rates. But the principal beneficiary of infrastructure investment in these large cities appears to be households, not firms. Even the highest of the infrastructure elasticity estimates in Table 4 is only 0.038, a figure which would not suggest that increased infrastructure provision would lead to a major increase in the productivity of city firms. We explore the implications of this finding further in the concluding section.

3.3. Results for other second stage variables[18]

Other second stage variables perform largely as expected. Climatological and locational amenities, where included, have statistically significant coefficients of the expected signs. As anticipated, the coefficient estimate on city land area is negative and significant in the land price equation and insignificant in the wage equation. Treated as perpetuities, local taxes are capitalized into land prices at rates near 100%.

The effects of state policy measures are instructive. In spite of the attention paid to interregional mobility, intrastate migration dominates American residential relocations. During the 1980s and early 1990s, between 80 and 90% of residential relocations were within the same state. What this suggests for the current model is that local and state fiscal policies may have substantially different effects. For example, while high city taxes may reduce the attractiveness of a city location, high state taxes may not, particularly if an active state government finances some (unmeasured) services that other cities must fund from their own tax bases. In such cases, higher state taxes will lead to higher city land values, as we consistently find here for state income taxes.[19] These findings underline the importance of careful attention to locational decision making in evaluating the effects of state and local fiscal policies. Models which combine the state and local sectors into aggregated measures implicitly assume that the effects of both are the same, but the evidence here is that they have substantially different effects, if only on particular locations.

[18] Details available upon request.
[19] Coefficients on the less progressive state sales tax rates were negative and insignificant.

4. Conclusions

While investments on the public agenda have evolved from canals and ports aimed at capturing the trade of unfinished agricultural products to fiber optic cable for providing internet bandwidth, part of the motivation for such investments has always been the idea that they provide some locations a competitive advantage vis a vis others (Pred, 1966; Markoff, 1997). But the implications of this spatial competition among regions has not played a large role in dominant approaches to modeling infrastructure impacts. The model and empirical evidence presented here emphasize the importance of infrastructure investments in affecting the relative attractiveness of places, potentially redirecting growth from infrastructure — poor areas to those which have invested more heavily.

The spatial equilibrium approach adopted here emphasizes the importance of infrastructure in altering the distribution of economic activity across regions, and re-establishes the household sector to its joint roles as consumer of infrastructure services, supplier of labor and competitor in the land market. The empirical evidence suggest that central city land prices are, ceteris paribus, positively associated with infrastructure provision and that the benefits of a growing public capital stock are likely enjoyed primarily by households. Nonetheless, substantial increases in city public infrastructure provision are unlikely to provide these cities with aggregate benefits sufficient to offset their costs.

Why do the infrastructure investments undertaken by the governments of older central cities seem, at the margin, to provide relatively modest local benefits? We offer several related explanations. Perhaps most important is our omission of cost and benefit spillovers. Because the analysis here counts only benefits that accrue to the central city, and ignores those that appear in neighboring suburban jurisdictions, the estimates presented here are a lower bound of the total value of such spending. In the presence of benefit spillovers, metropolitan areas may be faced with underprovision of public infrastructure in their central cities. In part as a response to this concern, a large share of infrastructure costs are borne by higher levels of government, reducing the city tax price of public capital. City decision makers are then induced to invest in public works beyond the level suggested by analysis of city benefits alone. Haughwout (1999)), however, finds evidence that central city infrastructure is still *underprovided* from the perspective of metropolitan areas as a whole.

Second, while these central cities are home to some of the nation's densest infrastructure stocks, they sustained substantial reductions in their historical roles as population and job centers over the second half of the twentieth century. While some of this change may be attributable to fiscal differentials, much of it is likely due to other factors (Mieszkowski and Mills, 1997). Since the mobile elements of these cities have declined faster than their stocks of public capital, many of them have infrastructure stocks built for larger resident populations and local job bases than they currently serve. As a result, a large share of the benefits generated by current central city infrastructure investment occurs in suburban jurisdictions.

Finally, the public investment decisions we observe are the result of local political processes, and may not be designed to maximize private sector economic returns. Many of the investments made by city governments, from land and equipment for neighborhood playgrounds to new plows for clearing residential streets more quickly after a snowfall, are primarily valued by households. Because residents vote and firms do not, it is perhaps unsurprising to discover that the marginal public investment dollar provides larger benefits to households than to firms.

These arguments suggest that the economic effect of infrastructure investments are heavily influenced by the political economy of the investment decision. In this paper, exogenously given infrastructure is envisioned as a contributor to local property values, underlining the complex relationships among local economic growth, the value of local tax bases and the level of infrastructure investment. It is clear that a careful analysis of the determinants of public investment is indicated. Modeling public investment is complicated by the fact that public capital is only one, albeit generally the largest, component of a portfolio of public assets and liabilities (Haughwout and Inman, 1996). The net local benefit generated by a program of long term borrowing to fund infrastructure investment is the crucial question faced by local decision makers and the municipal bond market (for preliminary evidence on this point, see Gyourko et al., 1997). The current model, with its emphasis on local equilibrium prices and quantities, provides the basis for examining the simultaneous structural relationship among local politics, tax bases, fiscal decisions and the real economy (Haughwout and Inman, 2000). As demonstrated here, the local price effects of public investments are central to our understanding of these complex phenomena.

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