Production, Consumption and the Rates of Return to Highway Infrastructure Capital*

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Abstract

A simple general equilibrium model is developed to measure the economic benefits of Infrastructure capital. We evaluate the effects of highway capital on the production and consumption side of the US economy. The rates of return of highway capital are found, taking into account the consumer and producer benefits as well as the distortions arising from taxation. The average distortion from financing highway capital with taxes is found to be 6.3% of the acquisition cost of highway capital. The net rate of return is found to be about 34% on average from 1949 to 2000. This rate of return however is found to be only 14% in the period 1990 to 2000 implying that there is not an underprovision of highway infrastructure capital.

*Preliminarily Draft

I. INTRODUCTION

There is a considerable amount of empirical evidence that public infrastructure capital contributes positively to lowering costs of production and thus contributes to the growth of output and productivity. In particular, highway capital, a major component of publicly financed infrastructure capital stock, is characterized by substantial network externalities that benefit all sectors of the economy. Some studies have attempted to estimate the rate of returns to infrastructure capital by looking at the benefits of public infrastructure on the production sector of the economy (e.g. Nadir and Mamuneas 1994, 1996; Demetriades and Mamuneas 2000) These studies however have ignore both the benefits to the consumers and the possible complications resulting from the fact that public investment is not financed by lump-sum taxation.

A modern highway infrastructure system has benefits not only for the producing sectors of the economy, but it also benefits consumers in facilitating travel to jobs, in vacationing, and in terms of general mobility. Therefore, there is a demand for services of highway infrastructure capital by the consumers. There are many studies addressing a number of very specific benefits and costs of highway capital and other transportation services to consumers. Unfortunately, very little evidence exists concerning these benefits for the aggregate consumption sector of the economy (references).

Another important overlooked issue, from the current literature, is the question of how the public infrastructure is financed. It is well known that when government finances the provision of public goods with lump-sum taxes the optimal condition is given by the sum of marginal benefits equal to the marginal cost of public goods. Samuelson's (and Kaizuka (1965)) condition when the cost of public goods has to be financed by distortionary taxes, should however be modified. In this second-best context, Pigou argued that the indirect damage (dead-weight losses) caused by distortionary taxes should be added to the cost of production to obtain the true opportunity cost of the public good. Therefore, the sum of marginal benefits of public goods should be equal to the marginal cost of production plus a term representing the marginal indirect damage (see for instance, King 1986 among others).

In this paper we formulate a simple general equilibrium model in order to take into account the effects of infrastructure capital on the production and on the consumption side of the economy. In addition we take into account any distortionary effects of financing public infrastructure through taxation. A general equilibrium approach would consider these effects explicitly. In this direction, Feltenstein and Ha (1999) and Rioja (1999) consider the effects of distortionary taxation on the economy but do not take into account the marginal benefits of infrastructure for consumers; furthermore, they use restrictive functional form specifications for both the production and utility functions.

The paper is organized as follows: section II is devoted to formulating a simple estimable model of optimal provision of public goods under a second-best environment. We formulate the social marginal benefit of the public (highway) capital and the gross and net rates of return to this type of capital for the entire economy. Econometric specification and estimation results are contained in section III. The model is estimated using aggregate U.S. data for the period 1949-2000. In this section, the estimating model is specified, the source of data and construction of the variables of the

model are described, and the estimation results are discussed. In section IV, the effects of highway capital on consumption expenditure decisions and on the production sector of the economy are presented. The estimates of total social marginal costs of highway capital and the implied gross and net rates of return to highway capital investment are also calculated and presented in this section. The last section presents the conclusions.

II. THE MODEL

We assume that both markets of goods and factors are competitive and therefore the production relationships can be described in terms of a profit function. Let y be an n - dimensional vector of variable net outputs. If $y > 0$ (< 0), then y is an output (input). Also, let p be the positive vector of variable input and output prices that the producers face, s, w are m - dimensional vectors of stocks that are available to producers at the beginning of the period and the corresponding *ex post* rental prices respectively, and g is an ℓ - dimensional vector of the stocks of infrastructure at the beginning of the year under consideration.

The technology is represented by a variable profit function (GNP function see Kohli, 1978) and is given by

$$\Pi(p, s, g, T) \equiv \max_{y_i} \left\{ \sum_{i=1}^{n} p_i y_i \mid (y, s, g) \in S^t \right\} \tag{1}$$

where T is an exogenous technology indicator and S^t is the private technology set at period t.

Also we assume that the individuals have preference defined over the traded private goods x and public capital g and the preferences of the whole economy, assuming identical consumers, may be represented by an expenditure function,

$$E(q, u, g) \equiv \min_{x_i} \left\{ \sum_{i=1}^{n} q_i x_i \mid U(x, g) = u \right\} \tag{2}$$

where q is a vector of consumers prices and u is the level of utility.

The relationship between producers and consumers prices is given by

$$q_i = p_i + t_i \tag{3}$$

where p_i is the producers price, $t_i (\geqslant 0)$ is a tax on goods $(i = 1, ..., n-1)$, and t_n is the tax on labor $(t_n \leqslant 0)$. Since infrastructure capital is assumed to be given from the point of view of producers and consumers we can define their implicit demand (or willingness to pay) functions as $-E_{g_k} = -\frac{\partial E(q,u,g)}{\partial g_k}$, and $\Pi_{g_k} = \frac{\partial \Pi(p,s,g,T)}{\partial g_k}$ respectively (Diewert 1980?).

Government's budget is given by

$$B = \sum_{i=1}^{n} t_i x_i - \sum_{k=1}^{m} c_k g_k \tag{4}$$

where B is the lump-sum transfer (tax), and c_k is the marginal cost of public good k. This is given by the rental price of public capital, defined as $c_k = p_k(r + \delta_k)$, where r is the rate of return, δ_k is the depreciation rate and p_k is its acquisition cost.

Assume now that the government chooses the tax rates t_i, and public goods g_k to minimize the deadweight loss of the economy subject to its budget constrain. Since the profit $\Pi(p, s, g, T)$ and expenditure $E(q, u, g)$ functions summarizes all the relevant aspects of production and consumption of the economy, a valid general equilibrium expression for the deadweight loss is

$$L(t, g) = E(q, u, g) - \Pi(p, s, g, T) - \sum_{i=1}^{n} t_i E_i + \sum_{k=1}^{m} c_k g_k \tag{5}$$

where $E_i = \dfrac{\partial E}{\partial q_i} = x_i$, from Shephard's lemma. The loss function is simply the value of the expenditure function at the gross of tax consumers prices and public highway capital that keep the consumers at the initial utility level u, minus the profits and net tax revenues collected and returned lump sum to the consumers (see Diamond and McFadden, 1974). The first terms measure the income necessary to compensate consumers to achieve utility level u, and the last terms is the lump-sum income available at the new compensated equilibrium.

Minimizing the Loss function given in (5) subject to the government's budget constraint (4), the Langrangian is

$$\begin{aligned} \pounds &= E(p + t, u, g) - \Pi(p, g, s, T) - \sum_{i=1}^{n} t_i E_i + \sum_{k=1}^{m} c_k g_k \\ &\quad + \lambda \left(\sum_{i=1}^{n} t_i E_i - \sum_{k=1}^{m} c_k g_k - B \right) \end{aligned}$$

Note that the relationship between producers and consumers prices is given by (3) where $q = q(t, g)$ and $p = p(t, g)$. In addition the market equilibrium conditions ($x_i = y_i$, $i = 1, .., n.$) are used to simplify the first order conditions. The first order conditions are:

$$\begin{aligned} \frac{\partial \pounds}{\partial t_\ell} &= E_\ell + \sum_{i=1}^{n} E_i \frac{\partial p_i}{\partial t_\ell} - \sum_{i=1}^{n} \Pi_i \frac{\partial p_i}{\partial t_\ell} - E_\ell - \sum_{i=1}^{n} t_i \left(E_{i\ell} + \sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial t_\ell} \right) \\ &\quad + \lambda \left[E_\ell + \sum_{i=1}^{n} t_i \left(E_{i\ell} + \sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial t_\ell} \right) \right] = 0 \end{aligned} \tag{6}$$

$$\begin{aligned} \frac{\partial \pounds}{\partial g_k} &= \sum_{i=1}^{n} E_i \frac{\partial p_i}{\partial g_k} + E_{g_k} - \sum_{i=1}^{n} \Pi_i \frac{\partial p_i}{\partial g_k} - \Pi_{g_k} - \sum_{i=1}^{n} t_i \left(\sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial g_k} + E_{ig_k} \right) + c_k \\ &\quad + \lambda \left[\sum_{i=1}^{n} t_i \left(\sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial g_k} + E_{ig_k} \right) - c_k \right] = 0 \end{aligned} \tag{7}$$

where $\Pi_i = \dfrac{\partial \Pi}{\partial p_i} = y_i$. Simplifying equations (6) and (7) (using the market clearing conditions) we

get

$$\sum_{i=1}^{n} t_i \left(E_{i\ell} + \sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial t_\ell} \right) = \lambda \left[E_\ell + \sum_{i=1}^{n} t_i \left(E_{i\ell} + \sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial t_\ell} \right) \right] \tag{6'}$$

$$-E_{g_k} + \Pi_{g_k} = (1-\lambda) \left[c_k - \sum_{i=1}^{n} t_i \left(\sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial g_k} + E_{ig_k} \right) \right] \tag{7'}$$

and solving (6') in terms of λ equation (7') can be written as

$$-E_{g_k} + \Pi_{g_k} = \tag{8}$$

$$\left[c_k - \sum_{i=1}^{n} t_i \left(\sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial g_k} + E_{ig_k} \right) \right] \left[\frac{E_\ell}{E_\ell + \sum_{i=1}^{n} t_i \left(E_{i\ell} + \sum_{j=1}^{n} E_{ij} \frac{\partial p_j}{\partial t_\ell} \right)} \right]$$

Equation (8) is the optimallity condition of public infrastructure capital under optimal distortionary taxation. The left hand side is the sum of marginal benefits to consumers and producers and the right hand side is the marginal cost of an increase of infrastructure capital. This is the optimal Pigouvian rule. The marginal willingness to pay must be equal to the marginal cost of public good grossed up by the effect of distortionary taxation in the economy. We have to evaluate however the effects of the changes of the infrastructure capital g_k and the tax rates t_ℓ on the prices ($\frac{\partial p_j}{\partial g_k}$, and $\frac{\partial p_j}{\partial t_\ell}$). These price changes are functions of both demand and supply derivatives through the market clearance equations.

To derive the effect of taxes and public infrastructure changes on the equilibrium prices, note that

$$E_i(p(t,g) + t, u, g) = \Pi_i(p(t,g), s, g, T) \ \forall i \tag{9}$$

and differentiating with respect to the ℓth tax rate t_ℓ we have

$$\left(\frac{\partial p_j}{\partial t_\ell} \right) = (M_{ij})^{-1} (X_\ell), \tag{10}$$

where

$$\left(\frac{\partial p_j}{\partial t_\ell} \right) = \begin{pmatrix} \frac{\partial p_1}{\partial t_j} \\ ... \\ ... \\ \frac{\partial p_n}{\partial t_j} \end{pmatrix}, (X_\ell) = \begin{pmatrix} -E_{1\ell} \\ ... \\ ... \\ -E_{n\ell} \end{pmatrix},$$

and

$$(M_{ij}) = \begin{pmatrix} E_{11} - \Pi_{11} & ... & ... & E_{1n} - \Pi_{1n} \\ E_{21} - \Pi_{21} & ... & ... & E_{2n} - \Pi_{2n} \\ .... & ... & ... & ... \\ E_{n1} - \Pi_{n1} & ... & ... & E_{nn} - \Pi_{nn} \end{pmatrix}$$

Differentiating (12) with respect to the kth infrastructure capital g_k we have

$$\left(\frac{\partial p_j}{\partial g_k}\right) = (M_{ij})^{-1}(Y_k) \tag{11}$$

where

$$\left(\frac{\partial p_j}{\partial g_k}\right) = \begin{pmatrix} \frac{\partial p_1}{\partial g_k} \\ ... \\ ... \\ \frac{\partial p_n}{\partial g_k} \end{pmatrix} \text{ and } (Y_k) = \begin{pmatrix} \Pi_{1g_k} - E_{1g_k} \\ ... \\ ... \\ \Pi_{ng_k} - E_{ng_k} \end{pmatrix}$$

Substituting equations (10) and (11) in (8) we have the optimallity condition for the public infrastructure capital for the whole economy. In elasticity form this condition is given by

$$-E_{g_k} + \Pi_{g_k} = c_k \left[\frac{1 - \sum_i \frac{t_i x_i}{c_k g_k} \omega_{ig_k}}{1 + \sum_i \frac{t_i x_i}{t_\ell x_\ell} \omega_{i\ell}} \right] \tag{12}$$

where

$$\omega_{ig_k} = \varepsilon_{ig_k} + \sum_j \frac{p_j}{q_j} \varepsilon_{ij} \eta_{jg_k}; \eta_{jg_k} = \frac{\partial p_j}{\partial g_k} \frac{g_k}{p_j}$$

and

$$\omega_{i\ell} = \varepsilon_{i\ell} + \sum_j \frac{p_j}{q_j} \varepsilon_{ij} \eta_{j\ell}; \eta_{j\ell} = \frac{\partial p_j}{\partial t_\ell} \frac{t_\ell}{p_j}$$

The left hand side of equation (12) is the social marginal benefit of infrastructure capital for the whole economy (consumers plus producers) and the right hand side is the social marginal cost. The gross rate of return of public infrastructure, k, is

$$\rho_k = \frac{-E_{g_k} + \Pi_{g_k}}{p_k(1 + t_k)}, \tag{13}$$

where

$$t_k = \left[\frac{1 - \sum_i \frac{t_i x_i}{c_k g_k} \omega_{ig_k}}{1 + \sum_i \frac{t_i x_i}{q_\ell x_\ell} \omega_{i\ell}} - 1 \right]. \tag{13'}$$

is the dead weight loss associated with the financing of public infrastructure capital and it is defined as a percentage of the acquisition cost of public infrastructure p_k.

III. EMPIRICAL IMPLEMENTATION

1. Expenditure Function Specification

To implement the above described model empirically, we assume that the expenditure function of the whole economy is given by the normalized expenditure function introduced by Diewert and

Wales (1988), augmenting it to include the highway capital g. The expenditure function is defined in Gorman-polar form by

$$e(q, g, u; T) = A(q, g) + B(q, g, T)u, \tag{14}$$

where T is the time trend (included to capture possible shifts of tastes over time), and A and B are unknown functions of prices and highway capital which should be specified. In order for the preferences to be well-behaved, the expenditure function should be linear homogeneous and concave in prices, q, and non-decreasing in utility, u. Let $(q,\ g,\ T) \gg 0_{n+2}$ and $u \geq 0$, and define

$$A(q, g) = \sum_{i=1}^{n} a_i q_i + a_g \left(\sum_{i=1}^{n} \theta_i q_i \right) g \tag{15}$$

and

$$\begin{aligned} B(q, g, T) = & \frac{.5 \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} q_i q_j}{\sum_{i=1}^{n} \theta_i q_i} + \sum_{i=1}^{n} b_i q_i + \sum_{i=1}^{n} c_{iT} q_i T \\ & + \sum_{i=1}^{n} d_{ig} q_i g + .5 d_{gg} \left(\sum_{i=1}^{n} \theta_i q_i \right) g^2 \end{aligned} \tag{16}$$

where a_i, a_g, b_i, b_{ij}, c_{iT}, d_{ig}, and d_{gg} are unknown parameters to be estimated, and θ_i are predetermined parameters. For the reference price $q^* = 1_n$, the parameters satisfy the restrictions

$$\sum_{i=1}^{n} \theta_i = 1, \sum_{i=1}^{n} a_i = 0, \text{ and } \sum_{j=1}^{n} b_{ij} = 0. \tag{17}$$

Note that the functions A and B are linear homogeneous in prices q, and therefore the expenditure function, e, is also linear homogeneous in prices. For the expenditure function to be concave in prices the $n \times n$ matrix $b = [b_{ij}]$ must be negative semidefinite. If this is not satisfied, Diewert and Wales (1988) have shown that this can be imposed by replacing b by the negative of the product of a lower triangular matrix a with its transpose a'. This implies that $b = -aa'$ where $a = [a_{ij}]$, $a_{ij} = 0$, $i < j$ (see also Wiley, Schmidt, and Bramble, 1973). This technique makes the expenditure function globally concave in prices in addition to preserving its flexibility properties.

For the highway capital, g, to positively effect individuals utility, the expenditure function should be non-increasing in g, i.e.,

$$\begin{aligned} \frac{\partial e(q, g, u; T)}{\partial g} &= \frac{\partial A(p, g)}{\partial g} + \frac{\partial B(q, g, T)}{\partial g} u \\ &= a_g \left(\sum_{i=1}^{n} \theta_i q_i \right) + \left[\sum_{i=1}^{n} d_{ig} q_i + d_{gg} \left(\sum_{i=1}^{n} \theta_i q_i \right) g \right] u \leq 0 \end{aligned}$$

In addition, in order for the marginal willingness to pay function, $w_k = -\frac{\partial e(q,g,u;T)}{\partial g}$, to be interpreted as the demand of highway capital, the expenditure function must be convex in g, i.e., $\frac{\partial^2 e}{\partial g^2} = d_{gg}(\sum_{i=1}^{n} \theta_i q_i) u \geq 0$; hence, for $u > 0$, $\sum_{i=1}^{n} \theta_i q_i > 0$, and $d_{gg} \geq 0$. If the estimated parameter is negative, we might replace d_{gg} by a square term such that $d_{gg} = d^2$ (see Diewert and

Wales, 1988). Finally, note that for the demand for highway capital to lie on the positive orthant, the condition $a_g\left(\sum_{i=1}^n \theta_i q_i\right) + \sum_{i=1}^n d_{ig} q_i u < 0$, for $g = 0$ must hold.

The Hicksian demand functions (using Shephard's lemma) are given by

$$\begin{aligned} x_i(q,g,u;T) &= \frac{\partial e(q,g,u;T)}{\partial q_i} = \frac{\partial A(p,g)}{\partial q_i} + \frac{\partial B(q,g,T)}{\partial q_i} u \\ &= a_i + a_g \theta_i g \\ &+ \left[\frac{\sum_{j=1}^n b_{ij} q_j}{\left(\sum_{i=1}^n \theta_i q_i\right)} - \frac{.5\theta_i \sum_{i=1}^n \sum_{j=1}^n b_{ij} q_i q_j}{\left(\sum_{i=1}^n \theta_i q_i\right)^2} \right. \\ &\left. + b_i + c_{iT} T + d_{ig} g + .5 d_{gg} \theta_i g^2 \right] u. \end{aligned} \tag{18}$$

The indirect utility function is given by equating (14) with total expenditures, $y = \sum_{i=1}^n q_i x_i$, and inverting it to get u, i.e.,

$$u = v(q,g,y;T) = \left[y - A(p,g)\right] / B(p,g,T). \tag{19}$$

Substituting in (18) the indirect utility we get the Marshallian demand functions as functions of consumers price, highway capital, income and time trend,

$$\begin{aligned} x_i(q,g,y;T) &= a_i + a_g \theta_i g \\ &+ \frac{y - A(p,g)}{B(p,g,T)} \left[\frac{\sum_{j=1}^n b_{ij} q_i}{\left(\sum_{i=1}^n \theta_i q_i\right)} - \frac{.5\theta_i \sum_{i=1}^n \sum_{j=1}^n b_{ij} q_i q_j}{\left(\sum_{i=1}^n \theta_i q_i\right)^2} \right. \\ &\left. + b_i + c_{iT} T + d_{ig} g + .5 d_{gg} \theta_i g^2 \right], \end{aligned} \tag{20}$$

where A and B are given by (15) and (16). To identify all the parameters of interest, we need an additional normalization. We normalize the public capital, and the time trend at the base period to be equal to one, $(q^*, g^*, T^*) = 1_{n+3}$, and we choose parameter restrictions such that $B(q^*, g^*, T^*) = 1$. The parameter restrictions are

$$\sum_{i=1}^n b_i = 1, \sum_{i=1}^n c_{iT} = 0, \text{ and } 2\sum_{i=1}^n d_{ig} = -d_{gg}. \tag{21}$$

Equations (20) together with the parameter restrictions (17) and (21) form the system of equations to be estimated.

2. Profit Function Specification

We assume that the functional form of π is the normalized quadratic introduced by Diewert and Wales (1988, 1992),

$$\begin{aligned}\pi(p,s,g,T) &= \sum_i c_{is}p_i s + \sum_i c_{ig}p_i g + \left(a_T T + a_{TT}T^2\right)\left(\sum_i \beta_i p_i\right)(\alpha_s s + \alpha_g g) \\ &\quad +.5\sum_i\sum_j a_{ij}p_i p_j\,(\alpha_s s + \alpha_g g)\left(\sum_i \beta_i p_i\right)^{-1} \\ &\quad +.5\left(b_{ss}s^2 + 2b_{sg}sg + b_{gg}g^2\right)\left(\sum_i \beta_i p_i\right)(\alpha_s s + \alpha_g g)^{-1}\end{aligned} \tag{22}$$

where p are the producers prices, s is the stock of private capital, g is the highway infrastructure capital and T is the time trend. The parameter α and β are chosen *a priori* to be the absolute value shares of the observed data at the base year. These are normalized such that

$$\alpha_s s^* + \alpha_g g^* = 1, \text{ and } \sum \beta_i p_i^* = 1 \tag{23}$$

where s^*, g^* and p^* are normalized to be 1 at the base year. The parameter vector c and the parameter matrices $a = [a_{ij}]$ and $b = [b_{k\ell}]$ are estimated subject to the following restrictions:

$$ap^* = 0 \text{ and } bk^* = 0 \tag{24}$$

where $k^* = (s^*, g^*)$. In order for the profit function to be convex in p and concave in $k = (s,\, g)$ the matrices a and b should be positive and negative semidefinite respectively. If this is not satisfied, Diewert and Wales (1988) have shown that this can be imposed by replacing matrices a and b by the following products of triangular matrix u and v respectively:

$$a = uu',\ b = -vv'$$

where $u_{ij} = 0$ for $i < j$, and $v_{k,\ell} = 0$ for $k < \ell$. This technique makes the profit function globally convex in prices and globally concave in fixed inputs in addition to preserving its flexibility properties.

Applying Hotteling's lemma in the profit function we have the net output supply functions

$$\begin{aligned}y_i(p,g,s;T) &= c_{is}s + c_{ig}g + \left(a_T T + a_{TT}T^2\right)\beta_i\,(\alpha_s s + \alpha_g g) \\ &\quad + \left[\frac{\sum_j a_{ij}p_j}{\sum_{i=1}^n \beta_i p_i} - \frac{.5\beta_i \sum_{i=1}^n \sum_{j=1}^n a_{ij}p_i p_j}{\left(\sum_{i=1}^n \beta_i p_i\right)^2}\right](\alpha_s s + \alpha_g g) \\ &\quad +.5\left(b_{ss}s^2 + 2b_{sg}sg + b_{gg}g^2\right)\beta_i\,(\alpha_s s + \alpha_g g)^{-1}\end{aligned} \tag{25}$$

Note that in the case of inputs (additionally differentiating π with respect to the private stock s)

we have

$$
\begin{aligned}
w_s(p,g,s;T) &= \sum_{i=1}^{n} c_{is}p_i + \left(a_T T + a_{TT}T^2\right)\left(\sum_{i=1}^{n}\beta_i p_i\right)\alpha_s \\
&\quad +.5\left(\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}p_i p_j\right)\alpha_s\left(\sum_{i=1}^{n}\beta_i p_i\right)^{-1} \\
&\quad +\left[\frac{b_{ss}s + b_{sg}g}{(\alpha_s s + \alpha_g g)} - \frac{.5\alpha_s\left(b_{ss}s^2 + 2b_{sg}sg + b_{gg}g^2\right)}{(\alpha_s s + \alpha_g g)^2}\right]\left(\sum_{i=1}^{n}\beta_i p_i\right)
\end{aligned}
\tag{26}
$$

The estimating equations are the equation set (25) and (26) together with the parameter restrictions (24).

3. Data Construction

Consumers

Consumption Goods: Data on consumption expenditures for the US economy have been obtained from the *National Income and Product Accounts* (*NIPA*) for the period 1948-2000[1]. We consider the following consumption expenditures, consumption (C), housing (H), motor vehicles (M), and transportation (R). The quantity of general consumption, x_C, and quantity of transportation services, x_R, are defined as total general consumption expenditures (minus the expenditures on housing and transportation) and total transportation expenditures (minus the expenditures of motor vehicles) divided by their corresponding consumers price deflators q_C and q_R respectively.

The stocks of housing and motor vehicles have been constructed using the perpetual inventory method, $K_{it} = I_{it} + (1-\delta_i)K_{it-1}$ $(i = H, M)$, where K is the stock and I is the gross expenditures in constant prices obtained from *NIPA*.[2] The depreciation rates have been obtained from *Bureau of Economic Analysis (BEA)* and are $\delta_H = 1.4\%$ for housing and $\delta_M = 31\%$ for motor vehicles. The initial capital stocks have also been obtained from *BEA*. The rental prices of housing and motor vehicles have been constructed as $w_i = \widetilde{p}_i(r+\delta_i)(1+t_i)$ $(i = H, M)$, where $\widetilde{p}_i$ is the acquisition price at producers prices, r is the rate of return and t_i is the effective tax rate on housing and motor vehicles respectively. The quantities of housing x_H and motor vehicles x_M are defined implicitly by multiplying their stocks with their rental prices and dividing by their corresponding rental prices normalized to be equal to 1 at the base period, q_H for housing and q_M for motor vehicles respectively.

Leisure: Total hours of leisure (ℓ) has been constructed by subtracting the total hours worked from the total endowment of hours available. To find the total endowment of time available, we assume that each person of working age has an endowment of two thousand hours available for leisure or work. Hence, the total endowment of hours available for the economy is equal to 2000 times the number of individuals between the ages 16 to 64 (data on population, N, have been obtained from

[1] Since price deflators in the new NIPA (1998) data set are available from 1959, we use old NIPA (1991) to splice the deflator.

[2] For housing, the gross expenditures, used in the perpetual inventory method, are one period lagged suggesting that the new housing stock is not available until the next period.

Economic Report of the President), i.e., $\overline{\ell} = 2000 \times N$. The total hours worked, L, is defined as the sum of total hours worked by the full-time and part-time employees (obtained from *NIPA*), plus the total hours worked by the self-employed. Assuming that the hours worked by the self-employed is equal to the hours worked by the full-time equivalent employees, the total hours worked by the self-employed is calculated as the average hours worked by a full-time equivalent employee times the number of self-employed. The number of self-employed workers is calculated by subtracting full time equivalent employees from persons engaged in production obtained from *Gross Product Originating* (GPO) *by industry.* Using hours worked by full-time and part-time employees from *NIPA*, the average hours worked by a full-time equivalent employee is calculated by dividing the hours worked by full-time and part-time employees by the number of full-time equivalent employees.

The labor income before tax, including that of the self-employed, VL, is estimated using compensation of employees from *GPO.* By dividing the total compensation of full-time and part-time employees by the number of full-equivalent employees and multiplying it by the number of self-employed, we obtain an estimate of the compensation of self-employed. Then, the total labor income before-tax is defined as the sum of compensation of full-time and part-time employees plus the compensation of the self-employed. The pre-tax wage rate, p_L, is defined by dividing the pre-tax labor income by the total hours worked; and the post tax wage rate is defined as $w_L = p_L(1 - t_L)$, where t_L is the effective labor tax rate. Finally, the quantity of leisure x_ℓ is defined by dividing the value of leisure ($w_L \ell$) by the normalized price of the post-tax wage rate, q_ℓ.

Taxes: We calculate effective tax rates for general consumption goods and labor by following the method described in Mendoza, Razin and Tesar (1994). One advantage of their method is that it is simple and the resulting tax rates summarize the information on statutory rates, deductions, credits, exemptions etc. In addition as the authors note these tax rates capture "the overall tax burden from each tax and maintain consistency with the representative agent framework" (Mendoza, *et al.*, 1994, p. 302).

We estimate the effective average tax rate on sales of consumption goods t_C by dividing the general taxes on goods and services plus the excise taxes (CT) by the private and government final consumption expenditures (GC) excluding the expenditure on housing[3] minus the compensation of employees paid by government (WG) minus the general and excise taxes, i.e., $t_C = \frac{CT}{GC - WG - CT}$. The general taxes on goods consist of state and local sales taxes[4]. State and local sales taxes and excise taxes are obtained from *NIPA*.

Note that this rate applies to expenditures of general consumption, motor vehicles, and transportation. However, motor vehicles are subject to additional taxes and housing is subject to property taxes. The effective rate applicable to motor vehicles expenditures is defined as $\tau_M = t_C + t_F$ where t_F is the motor vehicles license fee tax rate. The total effective rate is derived by $\tau_M = (t_C + \phi)/(1 - \phi)$, where $\phi = t_F/(1 + t_C + t_F)$ is calculated by dividing the motor vehicles license fee

[3] The expenditure on housing is excluded in order to get an appropriate tax base because we do not apply consumption tax to housing.

[4] The tax revenue data used in Mendoza, et al. (1994) were obtained from *OECD's Revenue Statistics.* To be consistent, we estimate each corresponding tax revenue in *OECD's Revenue Statistics* using government revenue from NIPA with same method used by *OECD* which is kindly provided by Tim Dobbs at BEA.

revenues (obtained from *NIPA*) by the total value of motor vehicles expenditures evaluated at consumers prices. The average effective motor vehicles tax rate applicable to the rental price, t_M, is then defined as $t_M = \tau_M \sigma_M/(r + \delta_M)$, where σ_M is the ratio of investment to capital stock. The effective property tax rate on housing is defined as $t_H = \tau_H/(r + \delta_H)$ where τ_H is calculated by dividing the value of property taxes on housing by the cost of housing stock. The property tax on housing is calculated by adding property taxes paid by individuals – except for real estate taxes – with indirect business tax and nontax payments by residents of owner-occupied homes obtained from *NIPA*.

To calculate the effective tax rate on labor income, t_L, we follow two steps since taxes on labor income are not directly observable. First, we calculate a tax rate on total income, and, assuming that all sources of household income[5] are taxed with the same rate, we calculate the tax revenues from total wage, TW, including the self-employed (constructed in the same way as total labor income). Second, by adding the contributions made to social security to the tax revenues we obtain the effective average rate of labor tax, t_L. This is defined as $t_L = (t_Y TW + TCS)/VL$, where t_Y is the income tax rate, VL is the total labor income (including self-employed), TCS is the total security contributions. The income tax rate t_Y is the ratio of individual income tax revenue to the total labor income. Wage and Salary have been obtained also from *GPO,* and data on social security contributions from *NIPA*.

Highway Capital: The highway capital stock g and its acquisition price p_g are obtained from Fraumeni (1999). The highway capital stock g has been normalized to be equal to 1 at the base year.

Producers

Outputs: We consider the following output categories, general consumption (C), motor vehicles (M), transportation service (R), export (E), and other goods (O) which include investment and government consumption. The quantity of general consumption, y_C, and quantity of transportation services, y_R, are same as those in consumption. The prices faced by producers of general consumption and transportation service are given by $p_i = \dfrac{1+sb}{1+t_C} q_i (i = C, R)$, where sb is subsidy rate and q_i is the consumers price. The value of general consumption and transportation in production are obtained by $p_i \cdot y_i (i = C, R)$

The motor vehicles output, y_M, is the gross expenditure in constant prices (I_M). The producers price of motor vehicles output, p_M, is the acquisition price of motor vehicles output which was calculated by dividing the price deflator of the gross expenditure in motor vehicles with $1 + \tau_M$. The value of motor vehicles output is then $p_M \cdot y_M$.

Other goods (O) include investment and government consumption (government compensation to employees). The quantity of other goods, y_O, is defined as total value of investment and government consumption by its price faced by producers, p_O. The price of other goods, p_O, faced by the producers is the weighted average of investment and government consumption price. Investment is defined as

[5] Household income includes proprietors' income with inventory valuation and capital consumption adjustments, rental, dividend and interest income which are obtained from *NIPA*.

private residential and nonresidential structure, and nonresidential equipment obtained from *NIPA*. Government consumption is obtained by subtracting government compensation to employees from total government consumption from *NIPA*. The price of government consumption faced by the producers is defined as $p_{GG} = \frac{1+sb}{1+t_C} q_{GG}$ where sb is the subsidy rate and q_{GG} is the price deflator for government consumption, excluding government compensation to employee.

The quantity of exports, y_E, is defined as the value of exports divided by its deflator, p_E. The exports price faced by producers is $p_E = (1+sb)p_E^*$ where p_E^* is the exports price before subsidy. Then value of exports in terms of producers price is $p_E \cdot y_E$.

Inputs: There are two variable inputs (imports and labor) and one fixed input (capital). The quantity of imports, y_I, is value of imports divided by its deflator. The price facing producers for imports is $p_I = (1+t_D)p_I^*$ where t_D is import duty rate (the ratio of import duties to the value of import) and p_I^* is the duty-free imports price. Then the value of imports in terms of producers price is $p_I \cdot y_I$.

To calculate private labor input, we subtract government compensation from total labor income (VL). The quantity of private labor input, y_L, is calculated by dividing value of pre-tax private labor income ($VL - VL^G$) by producers price of labor, p_L, which is the normalized pre-tax wage rate. Then total value of private labor input in terms of producers price is defined as $y_L \cdot p_L$. Finally, dividing values of all variable inputs and outputs by normalized producers price at the base year, we redefined quantities (y_i) of all inputs and outputs.

Private capital stock (K^P, non-residential equipment and structure) is assumed to be a fixed factor in the production. The stock of non-residential capital has been constructed using the perpetual inventory method with initial capital from *BEA*, $K_{Pt} = I_{Pt} + (1-\delta_P)K_{Pt-1}$, where I_{Pt} is the private fixed investment in constant price form *NIPA* and δ_P is the depreciation rate from *BEA* ($\delta_P = 5.7\%$). The rental price of private capital stock is estimated by $w_s = \tilde{P}_P(r+\delta_P)\frac{(1-u*z-itc)}{1-u}$, where $\tilde{P}_P$ is the acquisition price of private capital, r is the rate of return, u is the corporate income tax rate, z is the present value of depreciation deductions, and itc is the investment tax credit rate. z is constructed by $z = \frac{\alpha}{\alpha+i}$, where α is non-corporate and corporate capital consumption allowances (from *GPO*) over current value of capital stock and i is the long term interest rate (10-year U.S. treasury security from *Economic Report of the President*) .

Additional taxes in the production : Subsidy and import duty rates are calculated to construct prices facing producers. Subsidy rate sb is calculated by dividing subsidy (from *NIPA*) by the value of general consumption (VC, excluding housing, motor vehicles and transportation), transportation service (VR), government consumption (VG) and export (VE) in producers price minus subsidy[6] ($sb = \frac{Subsidy}{VC+VR+VG+VE}$). Import duty rate t_D is defined as import duty (from *NIPA*) over value of import.

[6] Here we implicitly assume that subsidy is applied only to consumption, excluding housing, motor vehicles, transportation service consumption and government consumption. According to subsidy to industries from *GPO*, most subsidy goes to agriculture, transportation and government sectors.

4. Estimation

consumers

Equations (20 are estimated in per capita terms. Both quantities and total outlays, y, have been divided by the population, N. All prices, q_i, the highway capital stock, g, and the time trend, T, have been normalized to be equal to 1 at 2000 (base period). The predetermined parameters θ_i $(i = C, H, M, R, \ell)$ have been set equal to the expenditure shares at the base period. To reduce heteroskedasticity we multiply both sides of the equations (20) with q_i/y and we append an error term ε_i in each equation. Since the systems of equations are not independent, we drop one equation when we estimate it. The estimation method used is the Iterative SUR.

In the general equilibrium, all prices can be expressed as a function of exogenous variables such as tax rates, highway capital, and private capital stocks. Therefore, we first regress prices on all exogenous variables and we use the fitted values of prices as instruments in the estimation.

The estimated parameters are reported in Table 1. The expenditure function is linear homogeneous and concave in prices. Initial estimation revealed that concavity in prices was not satisfied. Hence, we imposed concavity using the method proposed by Diewert and Wales (1988), described in the previous subsection.

Most of the parameters related to highway capital are significant. Jointly testing the highway capital parameters, using standard LR test ($LR(9) = 91.52$), rejects the hypothesis that the expenditure function is independent of highway capital. This is important because otherwise our indirect benefit analysis would be invalid. Hence, the demand for private goods can reveal the marginal willingness to pay for highway capital. Finally, we test whether or not tastes change over time (captured by the time trend) and we reject it.

producers

Equations (25) and (26) are jointly estimated. All prices p_i, the highway capital stock g, private capital stock s, and the time trend T have been normalized to be equal to 1 at 2000. The parameters α_i and β_i are chosen *a priori* to be the absolute value shares at the base year. To reduce heteroskedasticity, equation (25) is multiplied by $p_i / \left[\left(\sum_i \beta_i p_i\right)(\alpha_s s + \alpha_g g)\right]$ and equation (26) by $s / \left[\left(\sum_i \beta_i p_i\right)(\alpha_s s + \alpha_g g)\right]$. We again use the fitted value from the regression of prices on exogenous variables to instrument the prices. The estimation method used is the iterative SUR.

The estimated parameters are shown in Table 2. The profit function is convex in prices. Since the initial estimation did not satisfy convexity in prices, we again imposed the convexity using the method by Diewert and Wales (1988). Most of the parameters related to highway capital are significant. Using standard LR test ($LR(8) = 100.24$), we reject the hypothesis that the profit function is independent of highway capital.

IV. THE EFFECTS OF HIGHWAY CAPITAL

1. Highway Capital Elasticities

In this section we report the effects of highway infrastructure capital on the demand of demanded goods, supply of output and inputs. There is an interesting decomposition of the effect of public capital (or externalities in general) on the demand for private goods (see, for instance, Pollack, 1969; Cornes, 1980; and King, 1986, among others). This decomposition is very similar to the price decomposition of Slutsky. The effect of public capital in ordinary demands can be decomposed in two parts: one part is the substitution effect (holding utility constant) and the other is the expansion effect (allowing income to adjust). The elasticity of ordinary (Marshallian) demands with respect to highway capital is given by

$$\psi_{iG} = \varepsilon_{iG} - \varepsilon_{YG} \times \psi_{iY}$$

where $\psi_{iG} = (\partial x_i^m / \partial g)(g/x_i)$ is the Marshallian elasticity, $\varepsilon_{iG} = (\partial x_i^h / \partial g)(g/x_i)$ is the Hicksian elasticity and ε_{YG} and ψ_{iY} are the elasticities of cost and demand elasticity of income respectively. Hence, the total effect of highway capital depends on the substitution effect and the income effect. Note that if ε_{iG} is positive (negative), highway capital will be a complement (substitute) to private good i. Given that an increase of highway capital decreases private expenditures ($\varepsilon_{YG} < 0$)[7], or increases utility, the expansion effect will depend on the income elasticity of demand. Thus, due to an increase of public capital, consumers find themselves with higher income to spend from and, therefore, the income effect will be positive (negative) for a normal (inferior) private good.

The Marshallian elasticities, Hicksian elasticities, and the expansion effect of highway capital are reported in Table 3. The highway capital (as Hicksian demand elasticities indicate) is a substitute with consumption and motor vehicles, while it is a complement to public transportation, housing and leisure. First, the elasticity of consumption can be either positive or negative and at the same time be reasonable due to high level of aggregation. Second, public transportation and leisure look reasonable because new highways might increase public transportation service, and because more and better highways might increase leisure time (even though we do not model the time spent on highways explicitly). Finally, the substitution effect of highways and motor vehicles seems at first paradoxical since intuition suggests that more highways might increase the number of cars (new) on the roads. Here, though, the demand for motor vehicles is not expressed in to number of cars, but is modeled, rather, as deflated expenditures on new and used cars, accessories and parts. Expenditures on new cars were approximately 34% of total expenditures, whereas for used cars it was 20%, and 46% for the rest. Hence, it is not clear what the total effect might be. Also, we might think that an increase in the number of cars might increase the pressure on the government to expand the highway system, but the inverse might not be true. Thus we conclude that all our elasticities estimates are reasonable. Also, it should be noted that the Hicksian elasticities are evaluated keeping the level of utility constant.

[7] Using our estimates in Table 1, this elasticity is on average -.026 (std. err.=.009) for our sample period from 1949 to 2000.

By allowing the utility to adjust to a higher level, we have to consider the expansion effect of highway capital. In this case the highest expansion effect is in consumption followed by motor vehicles demand and leisure. Consumers, due to cost savings from an increase of highway capital, are now spending a higher proportion of the savings on motor vehicles and consumption than on other goods. However, the positive expansion effect is not enough to overcome the substitution effect in either motor vehicles or consumption. The elasticities of the Marshallian demands are reported in the last column of Table 3. The same pattern emerges as in the case of Hicksian demands. Consumers end up at a higher utility level with their demands for transportation and leisure having increased, while their demand for motor vehicles, housing and general consumption having declined.

In Table 4 we report the input and output elasticities of highway capital and private capital for comparison purposes. These elasticities are defined as $\zeta_{ik} = (\partial y_i/\partial k)(k/y_i)$ $k = g, s$. An increase of highway capital increases all inputs and outputs except export. [8]. Therefore, infrastructure capital is a gross complement to all variable of productions labor and imports and induces all the domestically supplied outputs. On the other hand private capital induces all inputs and outputs.

2 The Social Marginal Benefits and Cost of Highway Capital

The social marginal benefit, SMB_g of highway capital is calculated the sum of producers and consumers benefits. The consumers benefits are defined as $-N \cdot E_g$ where N is the size of the population and E_g is the reduction of the representative consumer expenditures due to an increase in highway capital services. The producers benefits are defined as Πg which is the increase of profits due to an increase of highway capital services. It has been shown, in a previous section, that under a second-best environment, absent lump-sum taxation, the social marginal cost of highway capital will be equal to its production cost plus a term which reflects the indirect damage due to the distortionary taxation. The social marginal costs are defined from the right hand side of equation (12). Hence

$$SMB_g = -N \cdot E_g + \Pi_g = c_g(1 + t_g) = SMC_g, \tag{27}$$

where t_g is the marginal damage due to distortionary taxation given by (13').

Then the gross rate of return, ρ_g, can be defined as

$$\rho_g = \frac{-N \cdot E_g + \Pi_g}{p_g(1 + t_g)}, \tag{28}$$

where p_g is the marginal cost of production of g assumed to be given by its acquisition price

In table 5, we report the social marginal benefits for producers and consumers, acquisition price of highway capital and the tax distortion effect by period. The social marginal benefit for consumers is 0.057 and for producers it is 0.066 on average from 1949 to 2000. It is interesting to note that the marginal benefits for consumers and producers have different patterns over time. Benefits for consumers have declined from the beginning of the period and started to increase in the 1980's while the producers benefits have increased in 1980's but have declined in 1990's. The tax distortion effect, t_g, is 0.063 on average and it has been varying.

[8] The profit elasticity of highway capital is 0.136 (std. err.=.062) on average from 1949 to 2000.

The last two columns of Table 5 report gross and net rate of return to highway capital for each period. The rate of return to highway capital is 0.357 on average for our sample periods from 1949 to 2000. The rate of return to highway capital reaches its highest point during the 1950's and declines gradually thereafter.

Net rate of return to highway capital stock ρ^* is calculated by subtracting the depreciation rate of highway capital from the gross return. This together with the long-term interest rate is illustrated in Figure 1. The net rate of return was fairly high at the beginning of the period in which the highway was being built, but it has been declining since 1970. At the end of the 1990's the two rates are very similar, implying that the highway capital is optimally provided. This is consistent with Nadiri and Mamuneas (1995) who find a similar pattern for the period 1950 to 1995.

V. CONCLUSION

In this paper we have developed and estimated a simple general equilibrium model in order to calculate the rates of return to highway capital for the US economy from 1949 to 2000. These rates of return have been estimated by taking into account consumers and producers benefits as well as the distortions arising from financing highway capital through taxation.

We have found that consumers and producers are willing to pay \$.057 and \$.066 respectively for an additional \$1 of public highway capital for the period 1949 to 2000. During the same period the average distortion from financing highway capital with taxes is found to be 6.3% of the acquisition cost of highway capital. In other words the social cost of a \$1 of an additional investment of highway capital is \$1.063.

Finally we have estimated that the average net rate of return to highway capital is about 34% from 1949 to 2000. This rate is much higher than the long term interest rate in the beginning of the period but both rates converge in the late 90's, implying no serious underinvestment in highway capital.

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Table 1: Parameter Estimates of Expenditure Function

Parameter	Estimate	Std. Error	Parameter	Estimate	Std. Error
a_C	-6220.17	2355.53	c_{CT}	6.63E-02	5.48E-02
a_H	4054.40	1929.16	c_{HT}	1.49E-01	3.89E-02
a_M	-491.71	837.22	c_{MT}	1.05E-02	1.05E-02
a_R	1214.74	461.66	c_{RT}	8.70E-03	6.35E-03
b_C	6.43E-01	9.94E-02	θ_{CG}	13896.00	2994.08
b_H	-8.58E-01	7.80E-02	θ_{HG}	-5132.58	1988.44
b_M	6.16E-02	2.93E-02	θ_{MG}	-1695.84	534.33
b_R	-3.91E-02	1.58E-02	θ_{RG}	1066.23	303.87
b_{CC}	-3.47E-03	8.38E-03	d_{CG}	2.52E-01	9.06E-02
b_{CH}	-6.99E-03	8.43E-03	d_{HG}	-1.14E-01	5.86E-02
b_{CM}	1.06E-02	1.29E-02	d_{MG}	-5.37E-02	1.64E-02
b_{CR}	-4.68E-03	5.65E-03	d_{RG}	5.81E-02	9.07E-03
b_{HH}	-1.49E-02	5.65E-03	**Equation**	**Std. Error**	$\mathbf{R^2}$
b_{HM}	2.13E-02	6.41E-03	Cons. Share	1.08E-02	0.71
b_{HR}	-9.42E-03	2.57E-03	Hous. Share	5.02E-03	0.95
b_{MM}	-3.22E-02	7.16E-03	Motor. Share	2.31E-03	0.61
b_{MR}	1.42E-02	2.78E-03	Trans. Share	1.12E-03	0.83
b_{RR}	-6.30E-03	2.83E-03			
		Log of likelihood = 913.59			

Table 2: Parameter Estimates of Profit Function

Parameter	Estimate	Std. Error	Parameter	Eatimate	Std. Error
a_T	279.86	7.27	c_{MS}	144.01	23.71
a_{TT}	-2.93	1.22E-01	c_{CS}	1591.74	84.97
a_{MM}	1.90	5.12E-01	c_{RS}	115.14	10.96
a_{MC}	57.60	7.75	c_{OS}	243.96	133.71
a_{MR}	3.81	5.67E-01	c_{ES}	822.45	67.72
a_{MO}	27.62	3.78	c_{IS}	-1592.18	66.20
a_{ME}	-4.06E-01	8.47E-01	c_{LS}	-5105.01	244.03
a_{MI}	29.20	3.91	c_{MG}	24.92	16.48
a_{CC}	1744.16	84.16	c_{CG}	838.21	86.93
a_{CR}	115.35	5.79	c_{RG}	10.35	8.94
a_{CO}	836.44	70.82	c_{OG}	649.05	95.38
a_{CE}	-12.30	25.34	c_{EG}	-392.46	46.83
a_{CI}	884.35	35.31	c_{IG}	-149.17	53.95
a_{RR}	7.63	5.52E-01	c_{LG}	-1638.67	200.54
a_{RO}	55.32	4.06	b_{SG}	-80.99	130.06
a_{RE}	-8.13E-01	1.66	**Equation**	**Std. Error**	$\mathbf{R^2}$
a_{RI}	58.49	2.37	Motor.	65.86	0.66
a_{OO}	401.13	55.36	Cons.	427.08	0.84
a_{OE}	-5.90	12.26	Trans.	27.82	0.36
a_{OI}	424.10	29.58	Other	511.50	0.50
a_{EE}	8.67E-02	3.58E-01	Export	244.07	0.40
a_{EI}	-6.24	12.98	Import	261.54	0.71
a_{II}	448.40	30.15	Labor	780.17	0.71
Log of likelihood = -2643.37					

Table 3: Demand Elasticities of Highway Capital: Slutsky Decomposition
(Mean Values, Std. Error in parenthesis)

	Substitution Effect (Hicksian)	**Expansion Effect**	**Total Effect (Marshallian)**
Quantity	(ε_{ig})	(-$\varepsilon_{yg} \times \psi_{iy}$)	(ψ_{ig})
Cons.	-0.1336	0.0413	-0.0923
	(0.034)	(0.013)	(0.025)
Hous.	0.0822	-0.0123	0.0699
	(0.067)	(0.006)	(0.062)
Motor	-0.1543	0.0172	-0.1370
	(0.171)	(0.011)	(0.182)
Transp	0.7159	0.0020	0.7180
	(0.347)	(0.011)	(0.358)
Leisure	0.0872	0.0121	0.0993
	(0.019)	(0.007)	(0.019)

Table 4: Input and Output Elasticities of Higway Capital and Private Capital
(Mean Values, Std. Error in parenthesis)

	Private Capital	*Highway*
Quantity	(ζ_{is})	(ζ_{ig})
Motor	0.8308	0.1692
	(0.026)	(0.026)
Cons.	0.7204	0.2796
	(0.033)	(0.033)
Transp.	0.8753	0.1247
	(0.022)	(0.022)
Other	0.5688	0.4312
	(0.035)	(0.035)
Export	1.9457	-0.9457
	(0.385)	(0.385)
Import	0.9335	0.0665
	(0.022)	(0.022)
Labor	0.7227	0.2773
	(0.044)	(0.044)

Table 5: Marginal Benefits, Cost, and Rates of Return to Highway Capital

	Marignal Benefit		Marginal Cost		Rate of Return	
	Consumers	**Producers**	**Production**	**Distortion**	**Gross**	**Net**
Period	$-N \cdot E_g$	Π_g	p_g	t_g	ρ	ρ^*
1949-2000	0.057	0.066	0.446	0.063	0.357	0.336
1949-1959	0.045	0.054	0.165	0.055	0.575	0.554
1960-1969	0.040	0.060	0.187	0.069	0.500	0.480
1970-1979	0.048	0.068	0.349	0.070	0.318	0.298
1980-1990	0.074	0.087	0.654	0.070	0.233	0.212
1990-2000	0.077	0.063	0.862	0.051	0.157	0.136

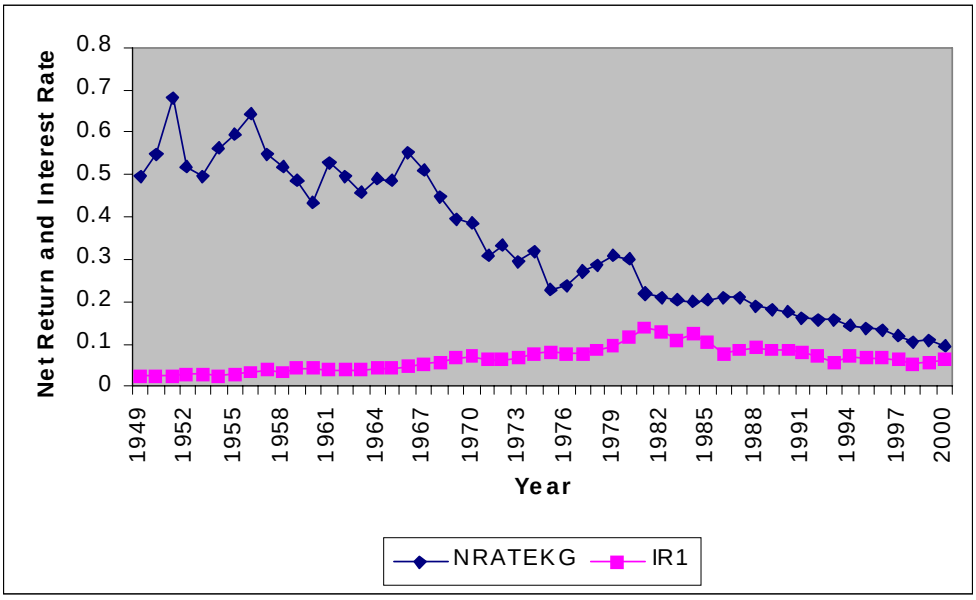

Fig. 1. Net Rate of Return to Highway capital and Long Term Interest Rate