NETWORK BENEFITS FROM TRANSPORT INVESTMENTS UNDER INCREASING RETURNS TO SCALE

A SCGE Analysis

by

Imdad Hussain & Lars Westin

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Network Benefits from Transport Investments under Increasing Returns to Scale. A SCGE Analysis.*

Imdad Hussain
Swedish National Road and Transport Research Institute (VTI)
S-581 95 Linköping,
Sweden

Lars Westin
Department of Economics and CERUM
Umeå University
S-901 87 Umeå
Sweden

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ABSTRACT

In a first-best best economy benefits from an improvement in a transport network may be measured completely by the change in consumer surplus under the general equilibrium transport demand curve on the improved link. This result is confirmed in a numerical three region SCGE model. However, impacts of distortions represented by increasing returns to scale are also considered in the paper. The extent to which benefits to traffic in this second-best case captures the welfare effects of the improvement is analysed. It is found that only if increasing returns prevail in the two regions directly connected by the improved link is it necessary to consider benefits beyond those measured on the link. The importance for the benefit measure of the size of investment, the elasticity of substitution in production, and the transport sector model formulation are evaluated. The most paradoxical result is where the region not located at the improved link obtains the largest benefits from the improvement. Other results confirm that in a flexible economy benefits from an improvement are less than in a more rigid economy and that the transport sector may act as an intermediary of distortions in the economy.

JEL classification: D58, D61, R13, R42

Keywords: Spatial cost-benefit analysis, infrastructure investments, spatial computable general equilibrium (SCGE), increasing returns to scale, second-best multimarket analysis.

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1. INTRODUCTION

Kanemoto and Mera (1985) proved that in a first-best economy, static economy-wide benefits of marginal as well as large improvements on a link in a trivial transport network may be captured by benefits to traffic under the ordinary general equilibrium transport demand curve. Other references in line with this result are Lesourne (1975), Dodgson (1973), and Jara-Diaz (1986). In the following, a three region SCGE model with the simplest possible, although non-trivial, network is introduced in order to simulate link related and economy-wide benefits of a transport investment in a static first-best economy.¹ As expected, our numerical simulations in this case confirm the theoretical result developed by Kanemoto and Mera in their two-region model.

On the other hand, deviations from first-best assumptions may lead to the result that total benefits of an improvement are not captured by a measure based on traffic on the improved link alone. However, little is known regarding those cases. An exception is the first attempts towards a general theoretical analysis presented in Just et al. (1982). Numerical simulations indicating the size of the difference between link related and economy-wide benefit measures are even less rare.

Our aim here is to investigate numerically how presence of increasing returns to scale in production influences the relationship between equivalent variation (EV) measured over all the three regions and the full benefits to traffic on the improved link. The question is to what extent total benefits of a transport improvement may still be approximated by considering traffic benefits alone.

In section two the SCGE model is presented, our benefit measures are given in section three while in section four the first-best case is considered. This gives a basis for comparison of the analysis with increasing returns to scale in section five. The numerical version of the model is solved using GAMS/MINOS.

¹ Friesz, Sou and Westin (1993) introduces this class of models. Takayama (1994) and Westin (1990a) give references to it's forerunners.
2. A THREE-REGION MODEL WITH AN ENDOGENOUS TRANSPORT SECTOR

The SCGE model consists of three regions connected by a transport network with six links. Each region is modelled with a representative consumer and a producer of a regionally specific good. Hence, the number of goods equals the number of regions and we may use \( i \) and \( j \) both for designating a certain region and the good produced in this region. Consumers demand goods from any region while the part of the labour not used for leisure is supplied as labour to the industry in their own region. Each industry and the common transport sector absorb goods as intermediate inputs.

The transport cost is added as a margin to the producer price and becomes proportional to this price. By this, high valued commodities are transported in a more expensive way, a fact not in complete conflict with observed behaviour.\(^2\) In the uncongested network, the transport cost coefficients are exogenously given by \( t_{ij} \), the generalised distance between regions \( i \) and \( j \). The factory gate price of good \( i \) is represented by \( p_i \). Since no taxes or other transaction costs are introduced, the buyer price \( p_{iy} \) becomes,

\[
p_i(1 + t_{iy})
\]

(2.1)

From (2.1) it is clear that \( p_i t_{iy} \) is received by the transport sector as revenue per unit of the transported good. To simplify we assume that revenues received by the transport sector from a region are fully spent on demand for the commodity produced in this region. This is of course only a special case of a more general demand function for the transport sector. This choice of demand structure will have no consequences for the evaluation as long as goods used by transport sector are priced at marginal cost. The transport sector's demand for good \( j \), \( X_j \), then is,

\[^2\text{An alternative specification is to define the unit transport cost independently of the price of the transported good. We have in the simulations considered both of these alternatives in order to confirm the generality of our results.}\]
\[ X_j = \sum_i p_i t_{ij} (X_{ij}^c + X_{ij}^d) / p_j \quad \forall j \quad (2.2) \]

In (2.2) \( X_{ij}^c \) is demand for good \( i \) by consumers in region \( j \) while \( X_{ij}^d \) gives the quantity of good \( i \) used as an intermediate input in production of good \( j \). Preferences for goods and leisure by households in region \( j \) are given by the following Stone-Geary utility function with usual properties,

\[ U_j = \sum_i \beta_{ij} \ln(X_{ij}^c - \bar{X}_{ij}^c) + \beta_{ij} \ln(H_j - \bar{H}_j) \quad \forall j \quad (2.3) \]

where \( U_j \) is the utility index for consumer \( j \), \( \bar{X}_{ij}^c \) is committed consumption of good \( i \), \( H_j \) is demand for leisure, and \( \bar{H}_j \) is committed leisure. The share of income spent by consumer \( j \) on good \( i \) is \( \beta_{ij} \) while \( \beta_{ij} \) determines demand for leisure. Those parameters of the utility function are given in Table 1 below and are kept unchanged during the simulations presented in this paper.

**Table 1** Parameters of the utility functions. Matrix of share parameters for commodities \( \beta_{ij} \) and leisure \( \beta_{ij} \).

<table>
<thead>
<tr>
<th>( \beta_{ij} )</th>
<th>To region:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>From region:</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>( \beta_{ij} )</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Households are spatially immobile and have a fixed endowment of 120 units of labour to be allocated between leisure and work. The demand for commodities and leisure is obtained from maximisation of (2.3) subject to the constraint,

\[ w_j (L_j - H_j) - \sum_i p_{ij} X_{ij}^c = 0 \quad (2.4) \]
where $\bar{L}_j$ is the endowment of labour in region $j$ and $w_j$ the wage rate. In the constant returns to scale case, profits will vanish in equilibrium while in the increasing returns to scale case the monopoly is regulated and characterised by zero profit pricing. By this we need not take care of flows of profits in the economy. The following system of linear expenditure demand functions for goods and leisure are derived from the simultaneous solution of the first order conditions of the utility maximisation problem,

$$X^e_i = \bar{X}^e_i + \frac{\beta_i}{P_i} \left[ w_j \bar{L}_j - w_j \bar{H}_j - \sum_i p_{ij} \bar{X}^e_i \right], \quad \forall i, j \tag{2.5}$$

$$H_j = \bar{H}_j + \frac{\beta_{ij}}{w_j} \left[ w_j \bar{L}_j - w_j \bar{H}_j - \sum_i p_{ij} \bar{X}^e_i \right], \quad \forall j \tag{2.6}$$

Although labour endowment is exogenous, labour supply is indirectly sensitive to relative prices through demand for leisure. Given demand for leisure, labour supply $L^s_j$ becomes,

$$L^s_j = \bar{L}_j - H_j \tag{2.7}$$

Each industry is described by a CES production function with labour $L^s_j$ and intermediate goods as inputs. Supply in region $j$ is thus obtained from,

$$X_j = \phi_j [\delta_u L^s_j + \sum_i \delta_{ij} X^s_i]^{-\zeta / \rho} \tag{2.8}$$

where $\phi_j$ is an efficiency parameter, $\zeta$ a scale parameter and $\rho$ determines the elasticity of factor substitution, $\sigma$ such that $\sigma = 1/(\rho + 1)$. Similarly $\delta_{ij}$ and $\delta_{ij}$ are distribution parameters which fulfil usual adding up conditions. The parameters of the production functions are given in table 2 below.
Table 2 Parameters of the production functions. Coefficients for intermediate inputs $\delta_y$ and a vector of labour demand coefficients $\delta_y$.

<table>
<thead>
<tr>
<th>$\delta_y$</th>
<th>To region:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>From region:</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>0.25</td>
</tr>
<tr>
<td>$\delta_y$</td>
<td>0.40</td>
</tr>
</tbody>
</table>

In our simulations, the efficiency parameter will be kept at one, while the scale parameter will be varied. Cost minimum gives first order conditions from which functions for factor and intermediate demand are derived. For the producer in region $j$ one obtains,

$$L^d_j = \left( w_j / \delta_y \right)^{-\rho(\rho+1)} \left[ \left( X_j / \phi_j \right)^{-\rho \zeta} / \left\{ \delta_y \left( \delta_y / w_j \right)^{-\rho(\rho+1)} \right\} \right]^{-1/\rho} + \sum_i \delta_y \left( \delta_y / p_i \right)^{-\rho(\rho+1)} \right]^{-1/\rho} \tag{2.9}$$

$$X^y_j = \left( p_j / \delta_y \right)^{-\rho(\rho+1)} \left[ \left( X_j / \phi_j \right)^{-\rho \zeta} / \left\{ \delta_y \left( \delta_y / w_i \right)^{-\rho(\rho+1)} \right\} \right]^{-1/\rho} + \sum_i \delta_y \left( \delta_y / p_i \right)^{-\rho(\rho+1)} \right]^{-1/\rho} \tag{2.10}$$

In equilibrium aggregate demand for goods equals supply while factor demand equals factor supply. The equilibrium is characterised by,

$$X_j = \sum_i X^y_{ji} + \sum_i X^y_i + X^y_j \quad \forall j \tag{2.11}$$

$$L^d_j = L^*_j \quad \forall j \tag{2.12}$$

The model may thus be reduced to six equations in six unknowns, i.e. the market clearing conditions and factor and commodity prices. Due to Walras law one of the equations becomes redundant and we end up with a system of five independent
equations in six variables. The wage in region three is used as a numeraire and set equal to one.

3. WELFARE MEASURES IN SPATIAL GENERAL EQUILIBRIUM

In the model an investment in infrastructure is introduced by a reduction in the size of the transport coefficients, \( t_y \). The "classical" question is whether the impacts of such an investment may completely be measured by the benefits to traffic on the improved links. Harberger (1971) showed that in a first-best economy the general equilibrium welfare effects of a minor change of policy in a single market may be captured by a measure of the consumer surplus under the ordinary general equilibrium demand curve in the same market. Lesourne (1975) showed that the general equilibrium effect of small as well as large scale transport improvements may be captured by the change in consumer surplus under the ordinary general equilibrium transport demand curve. Moreover, Kanemoto and Mera (1985) developed a general equilibrium model of a first-best economy with two regions and two goods by explicitly considering transport costs. It was found that an infinitesimal transport investment will not produce any measurable benefits over and above transport cost savings for existing traffic. However, transport cost savings for initial traffic underestimate the general equilibrium benefits of a large improvement. The difference between the two measures varies with the price elasticities related to the interregional demand for goods as well as with the size of the transport improvement.

Just et al. (1982) included cases of second-best in a general multimarket analysis. They showed that the general equilibrium effects of a new or altered distorting policy in a single market may completely be measured on the same market, provided that no price distorting mechanisms i.e. taxes, subsidies or deviations from marginal cost pricing exist in other markets and given that the government budget is unchanged. When the analysis is extended to cases with existing but unchanged distortions in other markets it is found that the general equilibrium effects of a price distorting policy in a single market in an already distorted economy may still be measured on this market. The conditions which must be fulfilled in this second-best case is that marginal cost pricing
prevails, there are no price floors or ceilings in the other markets while the net
government budget remains unchanged. If those conditions are not fulfilled, the impact
of the change on other markets has to be added to the impact on the link.

Given this, we are in the paper analysing the size of the difference between link and
economy-wide impacts when marginal cost pricing is abandoned in favour of an average
cost pricing rule in the case of increasing returns to scale. We also analyse the
importance of the size of the investment and of the elasticity of substitution on the
possibility to measure the total impact on the improved links alone.

In the following, general equilibrium benefits are calculated by aggregation of
equivalent variation (EV) over the three regions. EV is the change in income required to
take the consumer to the new level of utility at initial prices. Useful and well known
properties of EV are its path independence and the possibility to make ex-post
evaluations. Before we derive the EV measure used in this study it is although necessary
to define the term transport improvement more rigorously.

The quality of links between regions $i$ and $j$, $i \neq j$, are given by the non-negative
coefficient vector $\mathbf{t}^0 = (t^0_i, t^0_j)$. The pre-investment unit transport cost is then $\mathbf{m}^0(t^0)$,
where $\mathbf{m}^0$ has elements $m^0_{ij} = p^0_i t^0_{ij}$. The transport investment gives the new vector
$\mathbf{t}' = (t'_i, t'_j)$ and the post-investment unit transport cost vector is $\mathbf{m}'(t')$. The vector
which gives the continuous path of transport costs is denoted as $\mathbf{m}(t) = (m_{ij}, m_{ji})$. The
volume of transported goods follows a similar continuous path. The knowledge of the
exact curve obtained from those paths is necessary in case the welfare effect of the
improvement should be measured exactly by the change in the area under a transport
demand curve. From the equilibrium conditions it is obvious that the total flow on the
link between region $i$ an region $j$ is a function of the vectors of producer prices $\mathbf{p}$, wages
$\mathbf{w}$, and the unit transport cost such that $X_{ij}(\mathbf{p}, \mathbf{w}, \mathbf{m}(t))$. The benefits to traffic $\mathbf{B}^*$ from
a change in the transport coefficients from $t^0$ to $t'$ is then,
\[ B^* = - \sum_i \sum_j \int_{t_i}^{t_j} \left\{ X_{ij}(p, w, m(t)) \frac{\partial m}{\partial t} \right\} dt \] (3.1)

This may, by the substitution rule for the variable of integration, be changed to,

\[ B^* = - \sum_i \sum_j \int_{m_i}^{m_j} X_{ij}(p, w, m) dm \] (3.2)

Since we assumed that the entire network is uncongested, the transport cost on other routes remains unchanged. By this virtue, expression (3.2) may be simplified so that the full benefits to traffic is,

\[ B^* = - \int_{m_i}^{m_j} X_{ij}(p, w, m) dm - \int_{m_i}^{m_j} X_{ij}(p, w, m) dm \] (3.3)

However, due to the time consuming computations needed to identify the complete path of flows we will approximate this exact measure by the sum of transport cost savings for existing traffic plus the welfare change attributable to new traffic. The latter is approximated by a linear general equilibrium demand curve under the appropriate segment and by use of “the rule of a half” as shown below.

Let the total pre-improvement volumes of goods transported between region \( i \) and region \( j \) be given by \( X_{ij}^0 \) and \( X_{ij}' \). Then transport cost savings for existing traffic is,

\[ B^E = (m_{ij}^0 - m_{ij}) X_{ij}^0 + (m_{ij}' - m_{ij}) X_{ij}' \] (3.4)

According to the cost-benefit rules, the unit transport cost \( m_{ij} \) is always computed at initial producer prices. Moreover, let the post-improvement quantities be denoted by \( X_{ij}' \) and \( X_{ij}'' \). Then, the benefits associated with newly generated traffic, \( B^N \), become

\[ B^N = -1/2 \left[ \left\{ m_{ij}^0 - m_{ij} \right\} \left\{ X_{ij}' - X_{ij}'' \right\} + \left\{ m_{ij}'' - m_{ij} \right\} \left\{ X_{ij}'' - X_{ij}' \right\} \right] \] (3.5)
Hence, the precision of the linear approximation depends on the nature of the non-linearity in the transport demand functions. The total benefits to traffic $B^T$ is the approximation of $B^*$ and is given as,

$$B^T = B^E + B^N$$  \hspace{1cm} (3.6)

Given this, we may now derive the EV measure. Let $y_j$ be the disposable consumer income in region $j$, then the expenditure function is derived as the dual of the utility maximisation problem,

$$E_j = E_j\left(w_j^0, p_j^0, U_j^0\right) = \text{Min} \left[ \sum_i p_{i}^0 X_{i}^0 + w_j^0 H_j \right] \text{ s.t. } U_j\left(X_j^0, H_j\right) - U_j^0 = 0$$

Above, $U_j^0$ is the initial level of utility. The change from initial prices, wages and incomes in region $j$ may be characterised by the shift from $p_{i}^0, w_j^0, y_j^0$ to $p_{i}^1, w_j^1, y_j^1$ and an associated change in the utility to $U_j^1$. The equivalent variation for a consumer in region $j$ is obtained by taking the difference between the expenditure function at the new level of utility at initial prices and the expenditure function associated with the pre-improvement situation. Thus, the equivalent variation for the consumer in region $j$ is,

$$EV_j = E_j\left(p_{i}^0, w_j^0, U_j^1\right) - y_j^0 = E_j\left(p_{i}^1, w_j^1, U_j^1\right) - E_j\left(p_{i}^0, w_j^0, U_j^0\right)$$  \hspace{1cm} (3.7)

Equation (3.7) represents the change in consumer income required to provide the minimum of expenditure necessary to achieve the new level of utility at initial prices. The economy-wide benefit measure is obtained by aggregation of the benefits over regions,

$$EV = \sum_j EV_j$$  \hspace{1cm} (3.8)

Economy-wide benefits were by Tinbergen (1957) analysed in terms of the "Tinbergen multiplier" defined as the ratio of national income increase at initial prices to transport cost savings for existing traffic on the improved route. We have instead defined the
"True Benefit Multiplier" [TBM] as the ratio between the economy-wide benefit measure, EV and the traffic oriented benefit measure, $B^T$:

$$TBM = \frac{EV}{B^T} \quad (3.9)$$

A unitary value indicates parity between the two benefit measures. From theory parity would be expected in first-best economies. A multiplier value greater or less than unity indicate how accurately or badly the economy-wide benefit measure can be approximated by full benefits to traffic. However, since benefits to generated traffic are approximated by a linear transport demand segment one may even in "first-best" cases expect TBM to slightly deviate from unity.

The net benefits of a transport investment is also dependent on the full cost of the investment. Taxes may be used as a source of financing the transport infrastructure investment but in order to focus on impacts of increasing returns to scale we are simply not considering this investment cost aspect of the problem in this paper.

4. NETWORK IMPACTS OF A LINK IMPROVEMENT IN A FIRST-BEST ECONOMY

In this section we present the simulations of the first-best economy with all scale parameters assigned unit values. As mentioned the model consists of six links connecting the three regions which act as nodes in the network. Initially, the network is symmetric in the sense that transport coefficients are the same on all links as shown in table 3 below.

**Table 3** Pre-improvement inter-regional transport coefficients.

<table>
<thead>
<tr>
<th>REGION</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Table 4 below gives the pre-improvement equilibrium producer and consumer prices as well as inter-regional transport costs per unit of each good in the first-best case. Here, a solution with a unit elasticity of substitution is shown.

Table 4  Pre-improvement equilibrium consumer and producer prices, $p_i^0$ and $p_j^0$, with a unit elasticity of substitution. In parenthesis are the transport cost part of the prices given.

<table>
<thead>
<tr>
<th>REGION</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34.8 (0.0)</td>
<td>45.2 (10.4)</td>
<td>45.2 (10.4)</td>
</tr>
<tr>
<td>2</td>
<td>45.2 (10.4)</td>
<td>34.8 (0.0)</td>
<td>45.2 (10.4)</td>
</tr>
<tr>
<td>3</td>
<td>45.2 (10.4)</td>
<td>45.2 (10.4)</td>
<td>34.8 (0.0)</td>
</tr>
<tr>
<td>$p_f$</td>
<td>34.8</td>
<td>34.8</td>
<td>34.8</td>
</tr>
</tbody>
</table>

The table indicates the symmetric character of the initial equilibrium, in the sense that prices and transport costs are common to all links. The chosen elasticity of factor substitution changes the equilibrium solution. An increased elasticity will lead to an overall decrease in the price level since the economy becomes more flexible while the high price level in the less flexible economy reduces the overall activity. In the latter case, especially final demand is reduced since the possibility to substitute away intermediate goods is reduced. The increase in utility and purchasing power in the more flexible economy also encourages households to increase their demand for leisure in each region.

Table 5 below shows the quantity related part of the initial equilibrium. Final demand, intermediate inputs, transport demand and total supply of each good in the pre-improvement case for a unit elasticity of substitution are shown. In this case, final demand is only about a third of total supply of each commodity. Moreover, due to the limited demand for transportation the demand from the transport sector is also low.
**Table 5**  
Pre-improvement demand and supply of goods with a unit elasticity of substitution.

<table>
<thead>
<tr>
<th>From/to Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Demand</td>
<td>0.69</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>0.69</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>0.80</td>
<td>0.69</td>
</tr>
<tr>
<td>Total final demand</td>
<td>2.29</td>
<td>2.29</td>
<td>2.29</td>
</tr>
<tr>
<td>Intermediate demand</td>
<td>0.60</td>
<td>1.36</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td>1.36</td>
<td>0.60</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td>1.36</td>
<td>1.36</td>
<td>0.60</td>
</tr>
<tr>
<td>Total intermediate demand</td>
<td>3.32</td>
<td>3.32</td>
<td>3.32</td>
</tr>
<tr>
<td>Transport sector demand</td>
<td>1.29</td>
<td>1.29</td>
<td>1.29</td>
</tr>
</tbody>
</table>

| Total supply | 6.90 | 6.90 | 6.90 |

In table 6 income and utility relevant variables for three different elasticities of substitution are given. Since the three regions are equally endowed with technology and labour and have similar preferences, the values are relevant for each region.

**Table 6**  
Wage rates, leisure, incomes and utility indices for the pre-improvement case with different elasticities of substitution.

<table>
<thead>
<tr>
<th>Elasticity of substitution</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage rate</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Income</td>
<td>120.0</td>
<td>120.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Leisure demand</td>
<td>23.76</td>
<td>23.97</td>
<td>23.98</td>
</tr>
<tr>
<td>Utility level</td>
<td>1.51</td>
<td>6.59</td>
<td>8.77</td>
</tr>
</tbody>
</table>

The welfare impact of an increased elasticity of substitution is manifested as an increase in the level of utility, while incomes and the wage rate, given by the numeraire, are unchanged. Obviously may this increase in utility through increased flexibility be
compared with the change in utility obtainable by a reduction in the cost of interaction within a given level of flexibility.

Now, suppose that a transport investment is undertaken on the links between region one and region three. The transport coefficients are reduced by fifty percent, which results in a new set of equilibrium unit transport costs as given in table 7.

**Table 7** The post-improvement unit transport cost of good i carried to region j with a unit elasticity of substitution. Compare with table 4.

<table>
<thead>
<tr>
<th>From /to region</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0 (0)</td>
<td>10.1 (-)</td>
<td>5.0 (-)</td>
</tr>
<tr>
<td>2</td>
<td>10.7 (+)</td>
<td>0.0 (0)</td>
<td>10.7 (+)</td>
</tr>
<tr>
<td>3</td>
<td>5.0 (-)</td>
<td>10.1 (-)</td>
<td>0.0 (0)</td>
</tr>
</tbody>
</table>

A comparison of the post-improvement unit transport cost in table 7 and the corresponding pre-improvement situation in table 4 indicates as expected that the unit transport cost between region one and region three is reduced by more than half of the initial cost. This is due to the fact that the change in transport cost coefficients also reduced the equilibrium prices of the transported goods. The unit transport cost for shipping goods from region two has slightly gone up. This is explained by the increase in the price of good two. The post-improvement prices are shown below.

**Table 8** Post-improvement prices with a unit elasticity of substitution. Compare with the pre-improvement situation given in table 4.

<table>
<thead>
<tr>
<th>REGION</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.5 (-)</td>
<td>44.0 (-)</td>
<td>38.7 (-)</td>
</tr>
<tr>
<td>2</td>
<td>46.0 (+)</td>
<td>35.5 (+)</td>
<td>46.0 (+)</td>
</tr>
<tr>
<td>3</td>
<td>38.7 (-)</td>
<td>44.0 (-)</td>
<td>33.5 (-)</td>
</tr>
</tbody>
</table>

|  \( p_j \) | 33.5 (-) | 35.5 (+) | 33.5 (-) |
In table 9 the impact of these price changes on flows in the economy are given. The table indicates how the investment influences inter-regional flows, the transport sector's demand for resources and the equilibrium supply of goods. As a consequence of the increased cost of transportation, the flows of consumer goods from region two has decreased while this region instead consumes more of all goods.

<table>
<thead>
<tr>
<th></th>
<th>From \ To Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final demand</td>
<td>1</td>
<td>0.72 (+)</td>
<td>0.91 (+)</td>
<td>0.94 (+)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.78 (-)</td>
<td>0.75 (+)</td>
<td>0.78 (-)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.94 (+)</td>
<td>0.91 (+)</td>
<td>0.72 (+)</td>
</tr>
<tr>
<td>Total final demand</td>
<td></td>
<td>2.44 (+)</td>
<td>2.57 (+)</td>
<td>2.44 (+)</td>
</tr>
<tr>
<td>Intermediate demand</td>
<td></td>
<td>1.65 (+)</td>
<td>1.46 (+)</td>
<td>1.53 (+)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.46 (+)</td>
<td>0.65 (+)</td>
<td>1.46 (+)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.53 (+)</td>
<td>1.46 (+)</td>
<td>0.65 (+)</td>
</tr>
<tr>
<td>Total intermediate demand</td>
<td></td>
<td>3.64 (+)</td>
<td>3.57 (+)</td>
<td>3.64 (+)</td>
</tr>
<tr>
<td>Transport sector demand</td>
<td></td>
<td>1.08 (-)</td>
<td>1.34 (+)</td>
<td>1.08 (-)</td>
</tr>
<tr>
<td>Total supply</td>
<td>7.28 (+)</td>
<td>7.21 (+)</td>
<td>7.28 (+)</td>
<td></td>
</tr>
</tbody>
</table>

However, both region one and three increase their final demand since they now have to spend less resources on transport services. On the other hand, flows of intermediate inputs have increased due to the transport improvement. This increase may be explained by the relative reduction in the prices of intermediate inputs as compared to the cost of labour. Changes in labour supply, wage rates, incomes and utilities are given in table 10 below.

Each region improve its utility as a result of the transport cost reduction although the improvement never gives utility increases in parity with those obtained by an increased flexibility in the economy.
Table 10 Post-improvement wages, leisure demand, consumer incomes and utility indices with a unit elasticity of substitution. Compare with the pre-improvement outcome in column one of table 6.

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages</td>
<td>1.0 (0)</td>
<td>1.1 (+)</td>
<td>1.0 (0)</td>
</tr>
<tr>
<td>Income</td>
<td>120.0 (0)</td>
<td>131.7 (+)</td>
<td>120.0 (0)</td>
</tr>
<tr>
<td>Leisure</td>
<td>23.77 (+)</td>
<td>23.79 (+)</td>
<td>23.77 (+)</td>
</tr>
<tr>
<td>Utility</td>
<td>1.59 (+)</td>
<td>1.66 (+)</td>
<td>1.59 (+)</td>
</tr>
</tbody>
</table>

The average increase in utility from the investment amounts to 6.8 percent. However, especially region two, the one not located at the improved route, had a welfare impact (9.9 percent) which is above what were obtained in the two regions directly located at the route (5.3 percent). This paradoxical observation is in a sharp contrast to a simulation with a more flexible economy. In that case, although all regions improved their welfare, regions directly affected by the improvement benefited most.

The explanation of this paradox is related to the increased wage in region two. The reduced inter-regional demand for good two tends to move the price of this good upward. The wage rate in region two has to adjust to induce local consumption in order to clear the factor market. With this increase in income, region two consumes more of its own good and of leisure. Given the unit elasticity, the utility from this increase of income outweighs the negative effect of the price increase for the household in region two.

As was shown, increased flexibility gives higher levels of utility in all regions. However, the percentage change in utility in response to an infrastructure investment is largest in the least flexible economy. Hence, a flexible economy may always adjust to an inferior transport infrastructure and by this reduce the need for and the benefits of an improvement.
Although this gives interesting results regarding the activity in the spatial economy, our main interest here is the relation between benefits to traffic and benefits to the economy in the first-best case. We have analysed both ten and fifty per cent reductions in the transport cost coefficients. In order to examine the impact of the substitution elasticity, similar analyses are performed for different values of the elasticity. The results of our benefit calculations for a unit elasticity are given in table 11 below.

Table 11 Measures of benefits of improvements between regions one and three. A first-best economy with a unit elasticity of substitution.

<table>
<thead>
<tr>
<th>Reduction</th>
<th>$B^E$</th>
<th>$B^N$</th>
<th>$B^T$</th>
<th>$EV$</th>
<th>TBM</th>
<th>$B^N/B^T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 %</td>
<td>4.50</td>
<td>0.06</td>
<td>4.56</td>
<td>4.53</td>
<td>0.993</td>
<td>1.3</td>
</tr>
<tr>
<td>50 %</td>
<td>22.51</td>
<td>1.60</td>
<td>24.11</td>
<td>23.91</td>
<td>0.992</td>
<td>6.6</td>
</tr>
</tbody>
</table>

The table indicates that independent of the size of improvement $EV$ almost exactly equals the traffic benefit measure $B^T$. The small deviation between the two benefit measures obtained in the TBM may as discussed earlier be explained by the fact that benefits to traffic only provides an approximation of the exact benefit measure. Hence, we have confirmed that in the first-best economy total welfare gains of small as well as large scale transport improvements are captured by the full benefits to traffic on the improved route.

The absolute size of the benefits varies directly with the scale of improvement. As expected, the share of the benefits associated with newly generated traffic relative to total traffic benefits also increases with the size of the investment as is shown by the $B^N/B^T$ percentage ratio between generated traffic benefits and total benefits in table 11. The benefits due to newly generated traffic from a ten per cent reduction, represents little more than one per cent of the total transport cost saving. For a fifty percent reduction this ratio increases to above six per cent.
Moreover, the percentage ratio of EV to the total fixed labour endowment (EV/L) increases for a large scale investment and, although not shown here, decreases for higher values of the elasticity of substitution. The result is in line with our previous finding that the transport investment produces relatively less benefits in a more flexible economy. The most important result, however, derives from the significance of welfare gains associated with newly generated traffic. Although TBM maintains its unit value, the importance of newly generated traffic substantially increases with a large scale transport investment. *By omitting new traffic we will underestimate the benefits from the investment by six percent in this case of a large investment.*

5 THE CASE OF INCREASING RETURNS TO SCALE

With increasing returns to scale, the average total cost curve will have a negative slope and a market solution will give a monopoly solution. The monopoly will set the price above marginal cost in order to maximise profits. In case the monopoly is forced to set price equal to marginal cost, below average total cost, an operational loss is obtained. Here, the monopoly is regulated to set it's price equal to its average total cost in order to exclude the need to introduce public transfers or profits in the model. We examine how welfare gains of a transport investment change with this deviation from marginal cost pricing. Increasing returns to scale are introduced through the scale parameter in the production function which is set equal to 1.2 for the relevant producers.

Our analysis shows that the impact of positive returns to scale depends on the way transport costs are specified. In the first-best case they were proportional to the price of the transported good. The unit transport cost then became a reasonable proportion of the price of the good. However, under a monopoly, the unit transport cost will be set by the price level determined by economies of scale and the TBM becomes conditional on this. In order to evaluate the size of this impact our analysis is initially made with the producer price in the transport cost function based on average cost, named alternative (AI), and secondly by use of the marginal cost of the good produced with increasing returns, i.e. alternative (AII).
Table 12  Pre-investment equilibrium with increasing returns to scale based on transport price (AI) and a unit elasticity of substitution. Figures in brackets give the deviation from the first-best case in tables 4-6.

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer prices</td>
<td>1</td>
<td>8.8 (-26.0)</td>
<td>11.5 (-33.5)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>11.5 (-33.5)</td>
<td>8.8 (-26.0)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>11.5 (-33.5)</td>
<td>11.5 (-33.5)</td>
</tr>
<tr>
<td>Final demand</td>
<td>1</td>
<td>2.7 (+2.0)</td>
<td>3.2 (+2.4)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.2 (+2.4)</td>
<td>2.7 (+2.0)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.2 (+2.4)</td>
<td>3.2 (+2.4)</td>
</tr>
<tr>
<td>Intermediate demand</td>
<td>1</td>
<td>2.4 (+1.8)</td>
<td>5.4 (+4.0)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.4 (+4.0)</td>
<td>2.4 (+1.8)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5.4 (+4.0)</td>
<td>5.4 (+4.0)</td>
</tr>
<tr>
<td>Transport demand</td>
<td></td>
<td>5.1 (+3.8)</td>
<td>5.1 (+3.8)</td>
</tr>
<tr>
<td>Total supply</td>
<td></td>
<td>27.3 (+20.0)</td>
<td>27.3 (+20.0)</td>
</tr>
<tr>
<td>Leisure</td>
<td></td>
<td>23.9 (+0.1)</td>
<td>23.9 (+0.1)</td>
</tr>
<tr>
<td>Utility</td>
<td></td>
<td>4.6 (+3.1)</td>
<td>4.6 (+3.1)</td>
</tr>
</tbody>
</table>

The pre-investment equilibrium with prices set at average cost (AI) is shown in table 12. As expected, the solution is characterised by considerable price reductions and an increased output as compared to the corresponding first-best case. Subsequently, a substantial increase in the inter-regional flows are recorded. One may observe that increasing returns to scale has no substantial impact on the demand for leisure as the level of employment in the economy remains almost unchanged. Also in this case, we introduced two levels of infrastructure investments in the economy. The benefit calculations are summarised below in table 13.
Table 13 Measures of benefits due to transport improvements with increasing returns to scale, a unit elasticity and transport pricing alternative (AI).

<table>
<thead>
<tr>
<th>Reduction</th>
<th>$B^E$</th>
<th>$B^N$</th>
<th>$B^T$</th>
<th>EV</th>
<th>TBM</th>
<th>$B^N/B^T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>4.50</td>
<td>0.08</td>
<td>4.58</td>
<td>6.55</td>
<td>1.43</td>
<td>1.7</td>
</tr>
<tr>
<td>50%</td>
<td>22.50</td>
<td>2.07</td>
<td>24.57</td>
<td>34.95</td>
<td>1.42</td>
<td>8.4</td>
</tr>
</tbody>
</table>

The results in table 13 show that this alternative leads to a considerable discrepancy between traffic benefits and EV. However, note that transport cost savings for existing traffic remain almost at the same level as in the first-best model while the ratio of generated traffic benefits to total transport cost savings has increased. In the case of a fifty percent investment it reaches a level of eight percent as compared to six percent achieved in the first-best case. But the most substantial increase may be observed in the EV measure.

As the elasticity of substitution is increased the deviation between average total cost and marginal cost declines. Prices are reduced and equilibrium quantities increased. Hence, increased elasticity of substitution has an adverse effect on monopoly pricing, leading to a fall in the benefit multiplier. At a given degree of increasing returns to scale and elasticity of substitution, the size of the transport investment does not seem to have any influence on the TBM measure although the impact on the magnitude of benefits obviously is related to the size of the investment.

In transport cost alternative (AI) the transport cost structure was directly affected by the existence of increasing returns to scale in the production of a carried commodity. This may be avoided through approach (AII) where the unit transport cost is proportional to the marginal cost $mc_i$ of the transported good. Hence, the consumer price in this case is,

$$p_y = p_i + mc_i t_y$$

(5.1)

A comparison of the initial equilibrium situations based on (AI) and (AII) reveals that prices decline in the second alternative. Consumer prices were reduced by about 12
percent while the commodity flow increases. Nevertheless, the level of employment in the economy remains at the same level as in case (AI). Despite of the increase in the inter-regional flow, the transport sector’s demand for resources decline. This is due to the lower transport cost implied by case (AII). Our formulation according to (AII) also gives a higher utility level in each region. The results of a transport improvement based on (AII) is given in table 14 below.

As compared to alternative (AI) the level of traffic benefits has slightly increased while the equivalent variation has decreased considerably. Thus the true benefit multiplier now takes a much lower value since the unit transport cost is based on the marginal cost of the transported good.

Table 14 Measures of benefits due to transport improvements with increasing returns to scale and a unit elasticity. Transport costs are calculated according to (AII).

<table>
<thead>
<tr>
<th>Reduction</th>
<th>$B^E$</th>
<th>$B^N$</th>
<th>$B^T$</th>
<th>$EV$</th>
<th>TBM</th>
<th>$B^N/B^T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>4.67</td>
<td>0.07</td>
<td>4.74</td>
<td>5.66</td>
<td>1.20</td>
<td>1.5</td>
</tr>
<tr>
<td>50%</td>
<td>23.33</td>
<td>1.82</td>
<td>25.15</td>
<td>29.92</td>
<td>1.19</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Above, we find that traffic benefits are still short of $EV$ by about twenty percent but it was forty-three percent in case (AI). Hence, the impact transmitted through the transport sector seems to be rather substantial. Also in this case benefit measures computed for different values of the elasticity of substitution confirm the finding that the size of the true benefit multiplier varies inversely with the level of the elasticity of substitution in the economy.

In the analysis of increasing returns to scale we have so far assumed increasing returns in the production of all goods. However, in a spatial network context this need not be the case. Therefore, we have analysed the case of increasing returns only in region two, the node not directly located at the improved link, and also the case when increasing
returns only prevails in the two regions making the end points of the improved link. Given that the unit transport cost is defined as (AI) and increasing returns prevail only in the region located away from the improved route, all prices except for the good produced in region two are determined according to marginal cost. \textit{In this case the TBM equals one, a result verified independently of the degree of the elasticity of substitution.}

If the unit transport cost instead is defined as in (AI), the benefit multiplier only shows a slight deviation from unity. This deviation may, as we discussed earlier, be explained by the fact that the unit transport cost of the good shipped from region two is determined by a price which is not set according to it’s marginal cost. This gives an indirect impact on the price of the other goods. Also in this case, the small deviation is removed as the elasticity of substitution is increased in the economy. \textit{Our main conclusion thus is that increasing returns in production will have a substantial impact on the benefit multiplier only if the good produced under increasing returns is directly transported on the improved route.}

6 CONCLUSIONS

In this paper, we have examined the impact of increasing returns to scale on the relationship between traffic benefits and economy-wide benefits in a nontrivial network. The main result is that with increasing returns to scale in all regions, traffic benefits will underestimate equivalent variation considerably. The deviation between the two measures varies inversely with the elasticity of substitution. However, the deviation between traffic benefits and equivalent variation does not depend on the size of the improvement. It is although dependent on how transport costs are treated in the model. Moreover, if increasing returns to scale solely prevails in the production of commodities not transported on the improved road while other transported commodities are priced at marginal cost, traffic benefits either only slightly underestimate equivalent variation or exactly equals EV. The outcome is dependent on the formulation of the transport cost function.
When all prices are set equal to marginal cost the parity relationship between EV and traffic benefits holds. The ratio of generated traffic benefits to transport cost savings for initial traffic in all cases increase with the size of the transport improvement. Hence, in the evaluation of large scale transport investments, an estimation of newly generated traffic is crucial in order to get a realistic assessment of benefits. Transport cost savings for existing traffic only gives a lower bound of benefits.

REFERENCES


UMEÅ ECONOMIC STUDIES
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Umeå Economic Studies was initiated in 1972. For a complete list, see Umeå Economic Studies No 366 and earlier.


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Östbye, Stein: A Real Options Approach to Investment in Factor Demand Models, 1995.


Sjögren, Tomas and Brännäs, Kurt: Recreation Travel Time Conditional on Labour Supply, Work Travel Time and Income, 1995

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422 Cameron, A. Colin and Johansson, Per: Count Data Regression using Series Expansions: with Applications, 1996

423 Brännäs, Kurt: Count Data Modelling Measurement Error in Exposure Time, 1996

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428 Olsson, Christina: Chernobyl Effects and Dental Insurance, 1996. PhLic thesis

429 de Luna, Xavier: Projected Polynomial Autoregression for Prediction of Stationary Time Series, 1997

Hussain, Imdad and Westin, Lars: Tinbergen Revisited: Benefits from Infrastructure Investments in an Open Economy, 1997