Use of a Multiregional Variable Input-Output Model to Analyze Economic Impacts of Transportation Costs

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A multiregional variable input-output model is introduced to investigate the impact of a change in transportation costs on regional development and trade flows. Regional technical coefficients and trade coefficients are endogenous variables to the model and are sensitive to transportation costs as well as other input costs. Each industry is assumed to have a linear logarithm production frontier with a constant return to scale. Profit-maximizing price frontiers are obtained from the dual relation. These prices are expressed in terms of transportation costs, wage rates, land prices, input elasticities, and parameters of technical progress. These prices determine the regional technical coefficients and trade coefficients. The impact of a change in transportation costs on trade structure, regional growth, and inflation is investigated by using 1963 three-region, 10-sector interindustry flow data as a base. As expected, an increase in transportation cost between regions reduces the trade coefficient between the regions and increases the "own" trade coefficient; i.e., the purchases from other regions decrease and the purchases from local markets increase as the costs of transportation increase. An increase in transportation cost hampers regional development, but its sensitivity differs among industries.

Transportation cost plays a crucial role in determining regional development and trade flows. A lower transportation cost increases the trade flows among regions and contributes to regional development. A higher transportation cost reduces trade flows and deters regional development. An improvement in transportation facilities, such as the construction of highways, waterways, and railways, stimulates regional economic development and interregional trade flows, since such improvement reduces transportation cost. Impacts of an energy crisis, such as an increase in motor fuel costs, hamper regional growth and impede regional trade.

The U.S. Army Engineer Institute for Water Resources (IWR) is conducting an evaluation of the regional social, economic, and environmental effects of the McClellan-Kerr Arkansas River System project. That project, one of the major U.S. river basin developments, was dedicated in early 1971. The system provides navigation, flood damage reduction, hydroelectric power, water supply, and recreation for a large part of Arkansas and Oklahoma. At the same time that the navigation project was being built, an Interstate and toll-road system was developed that parallels the waterway and improves truck access. One of the significant problems in measuring the impact of such a system is determining the influence of lowered transport costs, attributable to the waterway, on regional economic development.

The research reported in this paper is directed toward developing an impact model that will show the with-project and without-project impacts of such a waterway.

LITERATURE REVIEW

Several models identify the relationship between the cost of transportation and regional development. One of the models that has successfully related transportation cost to regional development is Harris' multiregional, multi-industry forecasting model (1,2). The Harris model forecasts industrial outputs, employment, income, consumer expenditures, government spending, and population in 173 Bureau of Economic Analysis (BEA) economic regions and identifies industrial locations. The model introduces marginal transportation costs to explain those endogenous variables. Transportation costs enter the model with other factor costs such as wage rates, land costs, and capital costs. Marginal transportation cost is calculated by a linear programming transportation algorithm. The model identifies industrial locations in each region when there is a change in transportation costs among regions.

However, like many other regional econometric models, a paucity of regional data in the Harris model compels the model builder to choose explanatory variables that have the same trend as the dependent variables, e.g., lagged dependent variables. A long-run economic impact analysis requires stability in the estimated coefficients, and the Harris model appears to lack such stability (the model must reestimate the coefficients each year, since they vary over time). The model also fails to identify the cross-hauling of commodity trade among regions.

Other popular approaches to relating trade flows to regional development are multiregional input-output models (3-6). These models are popular tools for forecasting regional trade flows and developments. The major drawbacks of the multiregional input-output models are their assumptions on fixed technical coefficients and fixed trade structure. They fail to allow the trade coefficients and the technical coefficients to vary over time in response to change in transportation costs, wage rates, land prices, and capital costs.

Amano and Fujita (7) have modified the multiregional input-output model and traced the regional and national economic impact of improvements in transportation facilities. Their basic hypothesis is that improvement of a transportation facility lowers both the monetary and nonmonetary costs of transportation. The lower costs change the transportation service purchase coefficients and the trade coefficients. Such change would affect regional outputs and trade flows. The model assumes that only one row of technical coefficients—namely, the transportation service purchase coefficients—depend on the cost of transportation and all other technical coefficients remain unchanged. The model also assumes that only the trade coefficients between the two regions where transportation costs were changed are affected by the cost change and all other trade coefficients remain unchanged. It further assumes that the trade and technical coefficients are independent of a change in wage rates, land prices, local tax structure, and capital costs.

Our basic hypothesis is that firms choose inputs from each region so as to minimize costs and sell their products to each region and thus maximize their profits. The technical coefficients and the trade coefficients are simply results of such optimizing behavior of firms. Therefore, any change in input cost should change all technical coefficients and all trade coefficients because the firms substitute less expensive inputs for expensive

ones from each region. Transportation cost is one of the input costs, and any change in transportation cost should vary all technical and trade coefficients.

The multiregional variable input-output (MVIO) model described in this paper is derived from the basic duality between production and price possibility frontiers. From the dual relations, a set of price frontier equations is obtained. These prices in the frontier equations depend on input elasticities, transportation costs—both monetary and nonmonetary—wage rates, land prices, local tax rates, costs of capital goods, and parameters of technical progress. The equilibrium prices obtained from the price possibility frontiers affect the technical coefficients and the trade coefficients.

MULTIREGIONAL VARIABLE INPUT-OUTPUT MODEL

Consider an economy that has m regions and n commodities. Each industrial output in each region is assumed to be produced by a Cobb-Douglas production frontier:

$$\ln x_j^r - \alpha_{oj}^r - \sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \ln x_{ij}^{sr} - \gamma_j^r \ln L_j^r - \delta_j^r \ln K_j^r = 0$$

$$(j = 1, \ldots, n; r = 1, \ldots, m) \tag{1}$$

where

x_j^r = output of industry j located in region r,
x_{ij}^{sr} = intermediate purchase of the i th industrial output from region s by the j th industry located in region r,
L_j^r = labor service employed by the j th industry located in region r, and
K_j^r = service of capital employed by the j th industry located in region r.

α_{oj}^r, α_{ij}^{sr}, γ_j^r, and δ_j^r are parameters of the Cobb-Douglas production frontiers.

We assume linear homogeneity; namely,

$$\sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} + \gamma_j^r + \delta_j^r = 1 \qquad (j = 1, \ldots, n; r = 1, \ldots, m) \tag{2}$$

The purchase price of input is defined as the sum of the price in the producing region and the transportation costs of delivering the input to the final purchaser. The transportation costs include line-haul cost and terminal cost. For example, the purchase price of the i th input from region s by the j th industry in region r (p_{ij}^{sr}) is the sum of the price of the i th good in producing region s (p_i^s) and the cost of transportation of delivering one unit of the i th good from region s to region r ($\mu_i^{sr} \cdot p_i^s$); i.e.,

$$p_{ij}^{sr} = (1 + \mu_i^{sr}) \cdot p_i^s \tag{3}$$

The profit-maximizing input-output transformation functions are

$$-(f_j^r/f_{ij}^{sr}) = [(1 - t_j^r)\ p_j^r/c_i^{sr} p_i^s] \tag{4}$$

$$-(f_j^r/f_{Lj}^r) = [(1 - t_j^r)\ p_j^r/w_j^r] \tag{5}$$

and

$$-(f_j^r/f_{Kj}^r) = [(1 - t_j^r)\ p_j^r/v_j^r]$$

$$(i, j = 1, \ldots, n; r, s = 1, \ldots, m) \tag{6}$$

where f_j^r, f_{ij}^{sr}, f_{Lj}^r, and f_{Kj}^r are the partial derivatives of the Cobb-Douglas production frontiers with respect to x_j^r, x_{ij}^{sr}, L_j, and K_j. p_j^r, w_j^r, and v_j^r are the price of the j th good, wage rate, and service price of capital in region r; t_j^r is the effective tax rate on the j th industry in region r; and c_i^{sr} is the unity plus the unit transportation costs; i.e.,

$$c_i^{sr} = (1 + \mu_i^{sr}) \qquad (i = 1, \ldots, n; s, r = 1, \ldots, m) \tag{7}$$

From the input-output transformation functions (Equations 4-6), we derive the following profit-maximizing input demand equations:

$$x_{ij}^{sr} = \alpha_{ij}^{sr}\ (1 - t_j^r)\ p_j^r\ x_j^r/(c_i^{sr} p_i^s) \tag{8}$$

$$L_j^r = \gamma_j^r\ (1 - t_j^r)\ p_j^r\ x_j^r/w_j^r \tag{9}$$

$$K_j^r = \delta_j^r\ (1 - t_j^r)\ p_j^r\ x_j^r/v_j^r \tag{10}$$

From Equations 1-10, we obtain multiregional price frontiers:

$$\begin{aligned}
\ln p_j^r &= -\sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \ln[\alpha_{ij}^{sr}/(c_i^{sr} p_i^s)] - \alpha_{oj}^r \\
&\quad - \gamma_j^r \ln(\gamma_j^r/w_j^r) - \delta_j^r \ln(\delta_j^r/v_j^r) - \ln(1 - t_j^r) \\
&= -\sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \ln\alpha_{ij}^{sr} + \sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \ln c_i^{sr} - \alpha_{oj}^r \\
&\quad + \sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \ln p_i^s - \gamma_j^r \ln\gamma_j^r + \gamma_j^r \ln w_j^r \\
&\quad - \delta_j^r \ln\delta_j^r + \delta_j^r \ln v_j^r - \ln(1 - t_j^r)
\end{aligned} \tag{11}$$

Equation 11 can be conveniently stacked in the following matrix form:

$$(I - S) \ln p = h \tag{12}$$

where

$$S = \begin{bmatrix} \alpha^{11} & \cdots & \alpha^{1m} \\ \vdots & \ddots & \vdots \\ \alpha^{m1} & \cdots & \alpha^{mm} \end{bmatrix}', \quad \ln p = \begin{bmatrix} \ln p^1 \\ \vdots \\ \ln p^m \end{bmatrix}, \quad h = \begin{bmatrix} h^1 \\ \vdots \\ h^m \end{bmatrix},$$

$$\alpha^{sr} = \begin{bmatrix} \alpha_{11}^{sr} & \cdots & \alpha_{1n}^{sr} \\ \vdots & \ddots & \vdots \\ \alpha_{n1}^{sr} & \cdots & \alpha_{nn}^{sr} \end{bmatrix}, \quad \ln p^r = \begin{bmatrix} \ln p_1^r \\ \vdots \\ \ln p_n^r \end{bmatrix}, \text{ and}$$

$$h^r = \begin{bmatrix} h_1^r \\ \vdots \\ h_n^r \end{bmatrix}.$$

$$\begin{aligned}
h_j^r &= -\left(\sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \ln\alpha_{ij}^{sr} + \gamma_j^r \ln\gamma_j^r + \delta_j^r \ln\delta_j^r \right) \\
&\quad + \gamma_j^r \ln w_j^r + \delta_j^r \ln v_j^r - \ln(1 - t_j^r) - \alpha_{oj}^r \\
&\quad + \sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{rj}^{sr} \ln c_i^{sr}
\end{aligned} \tag{13}$$

The prime (′) denotes a transpose, and I is an (n • m) by (n • m) identity matrix.

The transportation cost of delivering commodity i from region s to region r is assumed to be the same regardless of the type of buyer; i.e.,

$$c_{ij}^{sr} = c_i^{sr} \tag{14}$$

where $c_i^{sr} = 1$ if $s = r$ and $c_i^{sr} > 1$ if $s \neq r$.

The price frontiers are expressed in terms of the cost of transportation $[c_i^{sr} = (1 + \mu_i^{sr})]$, effective tax rates (t_j^r), local wage rates (w_j^r), service price of capital (v_j^r), input elasticities $(\alpha_{ij}^{sr}, \gamma_j^r, \delta_j^r)$ and parameters of technical progress (α_{oj}^r).

In general, the profit-maximizing price level has a positive relation with the cost of transportation, effective tax rates, wage rates, and the service price of capital and a negative relation with parameters of technical progress. By jointly solving the price frontiers (Equation 12), we obtain (n·m) profit-maximizing price levels in terms of the cost of transportation, effective tax rates, local wage rates, service price of capital, input elasticities, and technical-progress parameters; i.e.,

$$p_j^r = p_j^r (c_i^{sr}, t_j^r, w_j^r, v_j^r, \alpha_{ij}^{sr}, \gamma_j^r, \delta_j^r, \alpha_{oj}^r) \tag{15}$$

From the profit-maximizing input demand equations, multiregional input-output coefficients are derived:

$$a_{ij}^{sr} = (x_{ij}^{sr}/x_j^r) = \alpha_{ij}^{sr} (1 - t_j^r) (p_j^r/c_i^{sr} p_i^s) \tag{16}$$

From Equations 15 and 16, we obtain the regional variable input-output coefficients, which are expressed in terms of transportation cost, effective tax rates, wage rates, service price of capital, input elasticities, and technical-progress parameters:

$$a_{ij}^{sr} = a_{ij}^{sr} (c_i^{sr}, t_j^r, w_j^r, v_j^r, \alpha_{ij}^{sr}, \gamma_j^r, \delta_j^r, \alpha_{oj}^r)$$
$$(i, j = 1, \ldots, n; s, r = 1, \ldots, m) \tag{17}$$

The regional technical coefficients are the sum of the regional input-output coefficients over regions; i.e.,

$$a_{ij}^r = \sum_{s=1}^{m} a_{ij}^{sr} \qquad (i, j = 1, \ldots, n; r = 1, \ldots, m) \tag{18}$$

The regional input-output coefficients are calculated by multiplying the trade coefficients by the regional technical coefficients; i.e.,

$$a_{ij}^{sr} = t_{ij}^{sr} \cdot a_{ij}^r \tag{19}$$

From Equation 19, the following relations are evident:

$$t_{ij}^{sr} = a_{ij}^{sr}/a_{ij}^r \qquad (i, j = 1, \ldots, n; s, r = 1, \ldots, m) \tag{20}$$

Variable trade coefficients are obtained and are expressed in terms of transportation cost, primary input prices, tax rates, and input parameters from Equations 17, 18, and 20:

$$t_{ij}^{sr} = t_{ij}^{sr} (c_i^{sr}, t_j^r, w_j^r, v_j^r, \alpha_{ij}^{sr}, \gamma_j^r, \delta_j^r, \alpha_{oj}^r) \tag{21}$$

The average trade coefficients are estimated as follows:

$$t_i^{sr} = (1/n) \sum_{j=1}^{n} t_{ij}^{sr} \tag{22}$$

Following Moses (4), it is assumed that each industry in region r consumes the same fraction of the import of commodity i from region s, so that the trade coefficients (t_{ij}^{sr}) are the same regardless of the final users; i.e.,

$$t_{ij}^{sr} = t_i^{sr} \tag{23}$$

The average trade coefficients (t_i^{sr}) in Equation 22 are the Moses type of trade coefficients. In our model, they are endogenously determined from the basic duality of production and price frontiers.

Regional outputs x are determined by the usual balance equations:

$$x = (I - TA)^{-1} Ty \tag{24}$$

where

$$\underset{(nm,\,1)}{x} = \begin{bmatrix} x^1 \\ \vdots \\ x^m \end{bmatrix}; \qquad \underset{(nm,\,nm)}{T} = \begin{bmatrix} T^{11} & \cdots & T^{1m} \\ \vdots & \ddots & \vdots \\ T^{m1} & \cdots & T^{mm} \end{bmatrix};$$

$$\underset{(nm,\,nm)}{A} = \begin{bmatrix} A^1 & \cdots & 0 \\ & A^2 & \vdots \\ 0 & \cdots & A^m \end{bmatrix}; \qquad \underset{(nm,\,1)}{y} = \begin{bmatrix} y^1 \\ \vdots \\ y^m \end{bmatrix};$$

$$\underset{(n,\,1)}{x^r} = \begin{bmatrix} x_1^r \\ \vdots \\ x_n^r \end{bmatrix}; \qquad \underset{(n,\,n)}{T^{sr}} = \begin{bmatrix} T_1^{sr} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & T_n^{sr} \end{bmatrix};$$

$$\underset{(n,\,n)}{A^r} = \begin{bmatrix} A_{11}^r & \cdots & A_{1n}^r \\ \vdots & \ddots & \vdots \\ A_{n1}^r & \cdots & A_{nn} \end{bmatrix}; \text{ and}$$

$$\underset{(n,\,1)}{y^r} = \begin{bmatrix} y_1^r \\ \vdots \\ y_n^r \end{bmatrix}.$$

x and y are (n·m) components vectors of regional output and regional final demand, respectively. T and A are (n·m) by (n·m) matrices of trade coefficients and regional technical coefficients.

TRANSPORTATION COST SIMULATION MODEL

The MVIO model responds to firms' efforts to minimize their input costs. The transportation cost ($c_i^{sr} = 1 + \mu_i^{sr}$; $s, r = 1, \ldots, m$; $i = 1, \ldots, n$) is one of such input costs, besides wage rates, capital cost, and land cost, that the firms face in the local economy. A change in one such input cost results in changes in equilibrium outputs, prices, regional technical coefficients, trade coefficients, and various multipliers in all regions. Table 1 provides input parameters, exogenous variables, and endogenous variables. The exogenous variables are assumed to be determined outside of the model. The input parameters are assumed to remain unchanged. Endogenous variables are the dependent variables of the model.

We describe here, step by step, how a change in one of the exogenous variables affects the endogenous variables of the model. The initial impact of such a change affects the equilibrium prices in all regions. To show the relations between exogenous variables and price

Table 1. Input parameters and exogenous and endogenous variables in the MVIO model and other multiregional input-output models.

		Variables	
Model	Input Parameters	Exogenous	Endogenous
MVIO	Input elasticities Technical-progress parameters	Wage rates Service price of capital, including land costs and capital costs Costs of transportation Effective tax rates Final demands	Industrial outputs, income, and employment Industrial prices Regional technical coefficients and interindustry transactions Trade coefficients and interregional trade-flow matrices Various multipliers
Others	Regional technical coefficients Trade coefficients	Final demands	Industrial outputs, income, and employment Regional interindustry transactions Interregional trade flows

levels, the price-frontier equations are rewritten, as follows:

$$\ln p_j^r = g_j^r + \Sigma\Sigma\ \alpha_{ij}^{sr}\ \ln c_i^{sr} + \gamma_j^r\ \ln w_j^r + \delta_j^r\ \ln v_j^r - \ln(1 - t_j^r) + \Sigma\Sigma\ \alpha_{ij}^{sr}\ p_i^s \quad (25)$$

where

$$g_j^r = -\alpha_{0j}^r - \Sigma\Sigma\ \alpha_{ij}^{sr}\ \ln\alpha_{ij}^{sr} - \gamma_j^r\ \ln\gamma_j^r - \delta_j^r\ \ln\delta_j^r \qquad (j = 1, \ldots, n;\ r = 1, \ldots, m) \quad (26)$$

Unless stated otherwise, $\Sigma\Sigma$ denotes $\sum_{s=1}^{m} \sum_{i=1}^{n}$.

The price-frontier equations are conveniently stacked in a matrix form:

$$(I - S)\ \ln p = g + W \cdot \ln c + \hat{\gamma}\ \ln w + \hat{\delta}\ \ln v - \ln(1 - t) \quad (27)$$

where

$$\underset{(nm,\,1)}{g} = \begin{bmatrix} g_1^1 \\ \cdot \\ \cdot \\ g_n^1 \\ \cdot \\ \cdot \\ g_n^m \end{bmatrix}; \qquad \underset{(nm,\,nmm)}{W} = \begin{bmatrix} S^1 & & & 0 \\ & S^2 & & \\ & & \ddots & \\ 0 & & & S^m \end{bmatrix};$$

$$\underset{(n,\,nm)}{S^r} = \begin{bmatrix} \alpha_{11}^{1r} \ldots \alpha_{n1}^{1r}, \ldots, \alpha_{11}^{mr} \ldots \alpha_{n1}^{mr} \\ \vdots \\ \alpha_{1n}^{1r} \ldots \alpha_{nn}^{1r}, \ldots, \alpha_{1n}^{mr} \ldots \alpha_{nn}^{mr} \end{bmatrix}; \qquad \underset{(nmm,\,1)}{\ln c} = \begin{bmatrix} \ln c_1^{11} \\ \vdots \\ \ln c_n^{11} \\ \vdots \\ \ln c_1^{mm} \\ \vdots \\ \ln c_n^{mm} \end{bmatrix};$$

$\underset{(mn,\,mn)}{\hat{\gamma}}$ = a diagonal matrix of γ_j^r;
$\underset{(mn,\,mn)}{\hat{\delta}}$ = a diagonal matrix of δ_j^r;
$\ln w$ = an $(m \cdot n)$ components vector of $\ln w_j^r$;
$\ln v$ = an $(m \cdot n)$ components vector of $\ln v_j^r$; and
$\ln(1 - t)$ = an $(m \cdot n)$ components vector of $\ln(1 - t_j^r)$.

The figure inside the parenthesis is the size of the matrix. The notation defined for the previous matrices is not defined here.

By taking a derivative of the price-frontier vector function (Equation 27) with respect to each cost vector, the relation between a change in cost variable and its impact on equilibrium prices is obtained:

$$\partial \ln p / \partial \ln c = [(I - S)^{-1}\ W]' \quad (28)$$

$$\partial \ln p / \partial \ln w = [(I - S)^{-1}\ \hat{\gamma}]' \quad (29)$$

$$\partial \ln p / \partial \ln v = [(I - S)^{-1}\ \hat{\delta}]' \quad (30)$$

$$\partial \ln p / \partial \ln(1 - t) = -[(I - S)^{-1}]' \quad (31)$$

The prime (′) denotes the transpose.

$[(I - S)^{-1}W)']$ is an $(n \cdot m \cdot m)$ by $(n \cdot m)$ transportation-cost-related price multiplier. It explains a corresponding change in equilibrium prices in each industry in each region that results from a 1 percent change in c_i^{sr}, which is unity plus rate of transportation cost $(1 + \mu_i^{sr})$. The transportation-cost-related price multipliers explain every detail of the impact of a change in transportation cost on the industrial prices in all regions.

A change in the transportation cost for a single commodity between two regions could affect the equilibrium prices of all commodities in all regions. The same rate increase in transportation cost for two different commodities yields completely different price effects in all regions. From the policy point of view, this is very important. It implies that construction of a waterway in Oklahoma and Arkansas could affect the price of bread purchased by a New Yorker. The increase in motor fuel cost may have different price effects depending on which commodity is being shipped with the motor fuel. The transportation-cost-related price multipliers provide details of such interesting questions.

The right-hand expressions of Equations 29-31 are price multipliers related to wages, the service price of capital, and the tax rate. All regional economies are interrelated. A change in wages, the service price of capital, or tax rates affects not only the industrial prices of that region but also those of all other regions. These chain impacts are traceable by those price multipliers.

Next, we evaluate how the changed prices that result from a change in transportation cost, wage rate, service price of capital, or effective tax rate would affect the multiregional input-output coefficients. These coefficients are decomposed into regional technical coefficients and trade coefficients.

From Equation 16, the following relation is evident:

$$\ln a_{ij}^{sr} = \ln \alpha_{ij}^{sr} + \ln(1 - t_j^r) + \ln p_j^r - \ln c_i^{sr} - \ln p_i^s \tag{32}$$

Suppose that the transportation cost is the only change in the economy; the rate of change in multiregional input-output coefficients can easily be identified, as follows:

$$\partial \ln a_{ij}^{sr}/\partial \ln c_i^{sr} = (\partial \ln p_j^r/\partial \ln c_i^{sr}) - 1 - (\partial \ln p_i^s/\partial \ln c_i^{sr}) \tag{33}$$

or

$$\partial \ln a_{ij}^{sr} = \partial \ln p_j^r - \partial \ln c_i^{sr} - \partial \ln p_i^s \tag{34}$$

The right-hand expressions in Equation 33 are simply transportation-cost-related price multipliers obtained in Equation 28.

Suppose that we have base-year multiregional input-output coefficients $a_{ij}^{sr}(t_0)$; the new input-output coefficients after the change in transportation cost $[a_{ij}^{sr}(t_1)]$ can be evaluated as follows:

$$a_{ij}^{sr}(t_1) = a_{ij}^{sr}(t_0) \exp(\partial \ln p_j^r - \partial \ln c_i^{sr} - \partial \ln p_i^s) \tag{35}$$

Note that $\partial \ln a_{ij}^{sr}$ is approximated by $\ln a_{ij}^{sr}(t_1) - \ln a_{ij}^{sr}(t_0)$ or $\ln[a_{ij}^{sr}(t_1)/a_{ij}^{sr}(t_0)]$.

The change in wage rate, service price of capital, and effective tax rate is traced in a similar way:

$$\partial \ln a_{ij}^{sr}/\partial \ln w_j^r = (\partial \ln p_j^r/\partial \ln w_j^r) - (\partial \ln p_i^s/\partial \ln w_j^r) \tag{36}$$

$$\partial \ln a_{ij}^{sr}/\partial \ln v_j^r = (\partial \ln p_j^r/\partial \ln v_j^r) - (\partial \ln p_i^s/\partial \ln v_j^r) \tag{37}$$

$$\partial \ln a_{ij}^{sr}/\partial \ln(1 - t_j^r) = [\partial \ln p_j^r/\partial \ln(1 - t_j^r)] + 1 - [\partial \ln p_i^s \div \partial \ln(1 - t_j^r)] \tag{38}$$

These multiregional input-output coefficients (a_{ij}^{sr}) decompose into the regional technical coefficients a_{ij}^r and trade coefficients t_i^{sr}, as explained in Equations 18-22.

EMPIRICAL FINDINGS

The variable input-output model responds to the optimizing behavior of firms in response to a change in input costs. Transportation costs, wage rates, and the service price of capital are important input costs to business firms. The service price of capital includes land cost and capital cost. Any change in these input costs affects firms' decisions on input demands and output prices. In this process, regional technical coefficients, trade coefficients, industrial growth, and regional inflation are changed.

The effect of a change in transportation costs on regional development and trade structures can be investigated by using 1963 interregional commodity flow data.

The U.S. Army Corps of Engineers system of regional classification divides the U.S. economy into three regions: (a) region 1—the Arkansas navigation region, which is a combination of Office of Business Economics (OBE) areas 117-119; (b) region 2—the west-south-central region (excluding region 1), which includes Texas, Louisiana, Arkansas, and Oklahoma; and (c) region 3—the rest of the United States.

U.S. industries are aggregated into 10 industrial sectors:

1. Agriculture, forestry, and fisheries;
2. Mining;
3. Construction;
4. Nondurable manufacturing;
5. Durable manufacturing;
6. Transportation, communication, and utilities;
7. Wholesale and retail trade;
8. Finance, insurance, and real estate;
9. Service; and
10. Federal, state, and local government.

The 1963 three-region, 10-sector interregional transaction table compiled by Kim (8) was used as the base-year data for this study.

A 5 percent change in transportation cost is introduced (a) between regions 1 and 2 (no change in transportation cost between regions 2 and 3 or regions 1 and 3), (b) simultaneously between regions 1 and 2 and regions 1 and 3 (no change between regions 2 and 3), and (c) among all three regions. The transportation cost is assumed to have changed for both delivering and receiving the commodities of the following industries: (a) agriculture, forestry, and fisheries; (b) mining; (c) nondurable manufacturing; (d) durable manufacturing; (e) finance, insurance, and real estate; and (f) service industries.

A 5 percent decrease in the cost of transportation between regions 1 and 2 substantially increases trade between these two regions. The percentages of goods imported by each of these two regions from the other, before and after the cost decrease, are given below:

	Percentage of Goods Imported			
	Region 1		Region 2	
Industry	Before	After	Before	After
Agriculture, forestry, and fisheries	33.68	34.73	5.05	5.35
Mining	61.87	62.78	1.25	1.32
Nondurable manufacturing	31.78	32.79	4.01	4.26
Durable manufacturing	19.95	20.76	3.78	3.99

The expansion of trade between regions 1 and 2 makes both regions reduce their industrial consumption of locally produced goods and their imports from region 3. This occurs because the cost to regions 1 and 2 of delivering and receiving goods from region 3 becomes relatively expensive, since it is assumed that there is no change in transportation cost between either regions 1 and 3 or regions 2 and 3 and only the transportation cost between regions 1 and 2 has changed.

When transportation costs were reduced between regions 1 and 2 and regions 1 and 3 at the same time, the trade coefficients of each region were lowered in all three regions. This implies that each region relies more on imports from other regions and less on locally produced goods. For example, in 1963, the "own" trade coefficients for nondurable manufacturing goods were 26.37 percent in region 1, 61.70 percent in region 2, and 94.22 percent in region 3. The own trade coefficient is the diagonal element of the trade-coefficient matrix. A 5 percent decrease in transportation costs between regions 1 and 2 reduces those own trade coefficients to 26.19 percent in region 1, 61.56 percent in region 2, and 94.20 percent in region 3. The simultaneous 5 percent decrease between regions 1 and 2 and regions 1 and 3 further reduces the own trade coefficients to 25.86 percent in region 1, 61.53 percent in region 2, and 94.16 percent in region 3. The 5 percent decrease among all three regions reduces these coefficients to 25.789 percent in region 1, 60.653 percent in region 2, and 93.878 percent in region 3. A decrease in own trade coefficients implies an increase in import coefficients—i.e., the off-diagonal coefficients of the trade-coefficient matrix. In general, the import coefficient has an inverse relation with the cost of transportation between two regions. Tables 2 and 3 give details of those changes for

Table 2. Trade coefficients of selected commodities before and after change in transportation cost.

		No Change (%)			5 Percent Decrease (%)					
					Between Regions 1 and 2			Between Regions 1 and 2 and 1 and 3		
Industry	Region	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3
Agriculture, forestry, and fisheries	1	30.61	5.05	1.57	30.30	5.35	1.59	30.00	5.41	1.68
	2	33.68	51.96	5.82	34.73	51.83	5.83	34.00	51.80	5.82
	3	35.71	42.99	92.61	34.98	42.82	92.59	36.00	42.80	92.50
Mining	1	17.44	1.25	0.89	16.91	1.32	0.90	16.87	1.32	0.95
	2	61.87	77.21	19.65	62.78	77.15	19.66	62.36	77.15	19.65
	3	10.69	11.55	69.45	10.31	11.53	69.44	10.77	11.53	69.41
Nondurable manufacturing	1	26.37	4.01	0.72	26.19	4.26	0.73	25.86	4.31	0.77
	2	31.78	61.70	5.06	32.79	61.56	5.07	32.02	61.53	5.07
	3	41.85	34.29	94.22	41.02	34.17	94.20	42.12	34.16	94.16
Durable manufacturing	1	18.27	3.78	0.91	18.18	3.99	0.92	17.82	4.04	0.98
	2	19.95	37.56	2.62	20.76	37.51	2.62	20.08	37.49	2.62
	3	61.78	58.66	96.47	61.06	58.51	96.46	62.10	58.48	96.40

Table 3. Trade coefficients of selected commodities for 5 percent increase and 5 percent decrease in transportation cost in all regions.

		5 Percent Decrease			5 Percent Increase		
Industry	Region	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3
Agriculture, forestry, and fisheries	1	29.910	5.267	1.679	31.316	4.848	1.467
	2	34.202	50.914	6.155	33.155	53.000	5.504
	3	35.887	43.820	92.167	35.529	42.152	93.029
Mining	1	16.838	1.311	0.937	18.064	1.188	0.854
	2	62.403	76.661	20.451	61.319	77.731	18.873
	3	10.760	12.028	68.612	10.617	11.081	70.272
Nondurable manufacturing	1	25.789	4.210	0.770	26.954	3.823	0.670
	2	32.188	60.653	5.352	31.375	62.730	4.794
	3	42.023	35.137	93.878	41.666	33.447	94.536
Durable manufacturing	1	17.776	3.901	0.976	18.778	3.654	0.853
	2	20.271	36.673	2.783	19.634	38.463	2.464
	3	61.953	59.425	96.241	61.589	57.884	96.683

the selected commodities before and after the deduction of a 5 percent decrease in transportation cost.

A 5 percent increase in transportation cost among all regions, which could be caused this year by the increase in Middle East crude petroleum prices, substantially increases the own trade coefficients in all three regions. For example, between the period before and after the 5 percent transportation cost increase, the own trade coefficient of durable manufacturing goods for region 1 jumps to 18.778 from 18.27 percent, to 38.463 from 37.56 percent in region 2, and to 96.683 from 96.47 percent in region 3.

Another interesting feature of this study is that the trade coefficient in all regions changes in response to a change in transportation cost between any two regions. The 5 percent decrease in transportation cost between region 1 and region 2 also changes the import structure of region 3. For example, after the reduction of transportation cost between regions 1 and 2, the region 3 importation of nondurable manufacturing goods from region 1 increases from 0.72 to 0.73 percent and its importation from region 2 increases from 5.06 to 5.07 percent. There is no change in transportation cost between regions 1 and 3 nor between regions 2 and 3, but their trade coefficients have changed.

The next item investigated is the effect on regional growth and deflation of the 5 percent decrease in transportation cost. Two cases are considered: Case 1 is a 5 percent decrease in transportation cost between regions 1 and 2, and case 2 is a 5 percent decrease in transportation cost among all three regions.

A 5 percent decrease in transportation cost between regions 1 and 2 stimulates region 1 the most. The nondurable manufacturing industry in region 1 grows as much as 2.99 percent, followed by agriculture at 2.94 percent, mining at 2.37 percent, and the durable manufacturing industry at 2.15 percent. The construction, financial, and service industries share the same growth rate: 0.79 percent. In region 1, the industries that exhibit the least growth effect are trade; government; and transportation, communication, and utilities. Their rates of growth are 0.30, 0.35, and 0.57 percent, respectively.

A relatively weaker impact is observed in region 2 in the above case. After the 5 percent reduction in transportation costs, agriculture, forestry, and fisheries grows only 0.53 percent, followed by durable manufacturing at 0.31 percent; mining at 0.29 percent; nondurable manufacturing at 0.28 percent; construction at 0.17 percent; finance, insurance, and real estate at 0.13 percent; and the service industry at 0.11 percent. Industrial growth rates in region 3 are virtually unaffected by the decrease in the cost of transportation between regions 1 and 2.

When a 5 percent decrease in transportation cost occurs among all three regions, the regional impact is much stronger than in the previous case. The agriculture, forestry, and fisheries industry in region 1 is stimulated as much as 9.78 percent in output growth—the largest growth rate among all industries. The output of the durable manufacturing industry increases 8.98 percent, followed by nondurable manufacturing at 7.53 percent, mining at 6.89 percent, construction at 2.58 percent, service at 1.90 percent, and transportation, communication, and utilities at 1.70 percent.

The 5 percent decrease in transportation cost among all regions also stimulates the industrial growth of region 2. The strongest growth rate again occurs in agriculture, forestry, and fisheries—5.50 percent—followed by durable manufacturing at 4.85 percent, mining at 3.40 percent, nondurable manufacturing at 3.25 percent, construction at 2.11 percent, and finance, insurance, and real estate at 1.08 percent.

Because the base-year industrial outputs in region 3

Table 4. Deflation and growth impact of 5 percent decrease in transportation costs.

		Regions 1 and 2 Only		All Regions	
Region	Industry	Output Change (%)	Price Decrease (%)	Output Change (%)	Price Decrease (%)
1	Agriculture	2.94	1.07	9.78	2.56
	Mining	2.37	0.48	6.89	0.98
	Construction	0.79	0.64	2.58	2.07
	Nondurable manufacturing	2.99	1.34	7.53	2.73
	Durable manufacturing	2.15	0.66	8.98	2.20
	Transportation, communications, and utilities	0.57	0.30	1.70	0.64
	Trade	0.30	0.19	0.93	0.44
	Finance	0.79	0.18	1.56	0.42
	Service	0.79	0.29	1.90	0.80
	Government	0.35	0.23	0.95	0.57
2	Agriculture	0.53	0.16	5.50	1.41
	Mining	0.29	0.05	3.40	0.37
	Construction	0.17	0.13	2.11	1.66
	Nondurable manufacturing	0.28	0.14	3.25	1.23
	Durable manufacturing	0.31	0.11	4.85	1.54
	Transportation, communications, and utilities	0.06	0.03	0.80	0.34
	Trade	0.04	0.03	0.36	0.24
	Finance	0.13	0.03	1.08	0.24
	Service	0.11	0.05	0.92	0.48
	Government	0.05	0.04	0.54	0.37
3	Agriculture	0.03	0.02	0.78	0.36
	Mining	-[a]	-[a]	0.55	0.16
	Construction	0.01	0.01	0.26	0.23
	Nondurable manufacturing	0.02	0.02	0.56	0.37
	Durable manufacturing	0.01	0.01	0.44	0.23
	Transportation, communications, and utilities	-[a]	-[a]	0.10	0.10
	Trade	-[a]	-[a]	0.02	0.04
	Finance	-[a]	-[a]	0.03	0.03
	Service	-[a]	-[a]	0.09	0.07
	Government	-[a]	-[a]	0.08	0.08

[a] Change smaller than 0.005.

are much larger than those of regions 1 and 2, the growth effect in region 3 is much smaller than that in either of the other regions. Region 3 covers the rest of the United States, excluding the west-south-central section. Because of the high base-year output, the percentage change in output—which is calculated by dividing the change in output by the base-year output—becomes relatively smaller. The growth rate in agriculture, forestry, and fisheries in region 3 is 0.78 percent, followed by nondurable manufacturing at 0.56 percent, mining at 0.55 percent, durable manufacturing at 0.44 percent, and construction at 0.26 percent. Trade, finance, service, and government are highly insensitive to the transportation cost change. Their growth rates are only 0.02, 0.03, 0.09, and 0.08 percent, respectively.

Transportation cost is a part of business cost, and lower transportation cost between regions 1 and 2 further lowers the price of nondurable manufacturing goods in region 1 by as much as 1.34 percent. Farm price is reduced by 1.07 percent, the price of durable manufacturing goods by 0.66 percent, and construction service price by 0.48 percent. The price impact in region 2 is observed mostly in the farming industry, where the price decreases by 0.16 percent, followed by nondurable manufacturing goods at 0.14 percent, construction at 0.13 percent, and durable manufacturing goods at 0.11 percent.

The price impact of the decrease in transportation cost is much stronger when the decrease occurs among all three regions. The biggest price decrease occurs in region 1 in nondurable manufacturing goods, the price of which goes down by as much as 2.73 percent. The prices of agricultural products, durable manufacturing goods, construction services, and mining products are down by 2.56, 2.20, 2.07, and 0.98 percent, respectively. The same industrial groups in region 2, except mining, show the largest price declines in regions 2 and 3 in response to the 5 percent decrease in transportation cost among all regions.

Agriculture, durable and nondurable manufacturing, construction, and mining are generally highly sensitive to both changes in output and price and a change in transportation costs. The growth and price responses of government; service; finance; trade; and transportation, communication, and utilities are less sensitive to transportation cost change.

Table 4 gives data on the deflation and growth impact of a change in transportation costs.

CONCLUSIONS

Regional technical coefficients and trade coefficients are endogenous variables to the MVIO model. These coefficients are the results of the optimizing behavior of the firms in each region. Transportation cost is one of the input costs that the firms wish to minimize. A change in transportation cost affects the regional technical coefficients and the trade coefficients because the firms' input mix from each region has to be changed.

A major limitation of the model is the assumption on the linear logarithm production frontier. The specification implies a unitary elasticity of substitution between a pair of inputs and a constant share of input. The input share as an approximation to the input elasticity may be another limitation of the model.

The model shows that the regional technical coefficients and the trade coefficients are sensitive to the change in transportation costs. In general, an increase in transportation costs forces firms to buy and sell more of their products in their local markets and to import less of their inputs from other regions. The own trade coefficients increase as transportation costs increase. The cross trade coefficients, which are the off-diagonal elements of the trade-coefficient matrix, decrease as transportation costs increase. The sensitivity of trade coefficients to the change in transportation costs differs among commodities. Manufactured goods are more vulnerable to the cost change than are agricultural goods.

Transportation costs affect regional development and inflation. Some industries are more susceptible to the change in transportation cost than others. In general, manufacturing, mining, and agriculture are more susceptible, whereas trade, government, and communications are less susceptible.

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Discussion

Hays B. Gamble

The main contribution of the paper by Liew and Liew appears to be one of adopting a methodological approach (interregional input-output) to the analysis of the effects of changes in transportation costs. They assume a 5 percent change in such costs, but the effects on trade coefficients are quite slight, well within the normal variations that exist, solely because of errors in data measurement. Moreover, they use 1963 data, which are too old to have much meaning. Their findings are therefore really quite meaningless, and any merit of the paper must rest on the methodological adaptation of interregional input-output. I think this point should be stressed.

Authors' Closure

The empirical results presented in our paper should be considered as an illustration of the working of the model. The data need to be updated for current policy evaluation, but the implications of the empirical results should provide interesting insight for transportation planners and the freight industries.

We are not sure precisely what "errors in data measurement" means. The effect on trade coefficients is simply a result of the simulation of the model. Elsewhere, we compiled the effect on trade coefficients under varying degrees of change in transportation cost, and the impacts are significant.

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Quantitative Technique for Estimating Economic Growth at Nonurban, Limited-Access Highway Interchanges

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A quantitative modeling technique for estimating the economic development that is likely to occur at a given nonurban interchange site on the Interstate highway system is described. It was important that the model be easily implemented by using secondary data on economic, demographic, geographic, and other characteristics. A sample of 128 nonurban Pennsylvania interchanges was selected. Problems in the quantification of variables and restrictions imposed by the lack of data for certain variables were discussed. Simple, multiple, and stepwise linear regressions were useful in identifying promising variables for the modeling technique. The structural design of the model was formulated by using 15 exogenous variables that define the economic, demographic, geographic, and traffic environment and the following five endogenous variables: service stations, restaurant seats, motel rooms, industrial developments, and other commercial developments. The forecasting model consisted of a set of simultaneous linear equations. The simultaneous-equation model usually gives better estimates than single-equation models. A two-stage least-squares technique was used to estimate the parameters of the model. All equations of the model were statistically significant. The model can be a useful tool in helping planners to predict land use changes at existing or proposed nonurban interchange sites. When applying it to a specific interchange, the user is cautioned to observe the total environmental setting for peculiar or unique characteristics.

An important provision of the Federal-Aid Highway Act of 1956, which authorized the Interstate highway system, was the prohibition on roadside developments such as gasoline stations, restaurants, and motels with direct access to Interstate rights-of-way. Since traffic to and from a limited-access highway must be channeled through an interchange and highway users traveling long distances do not ordinarily want to go far from an interchange in search of gasoline, food, or lodging, an interchange is