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A transportation-oriented interregional computable general equilibrium model of the United States

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Abstract. Interregional computable general equilibrium (ICGE) models are useful new tools for investigating questions of spatial equity and efficiency, especially if they consider the explicit costs of movement across space. In this paper, we outline a three-region, five-sector operational ICGE model of the United States which has been calibrated from a 51 region, 124 sector public data base. This model explicitly includes transportation and wholesaling services and the costs of moving products based on origin-destination pairs. Through the use of a counterfactual scenario, the ICGE's explicit specification is compared with a well known implicit method – to observe how the predicted regional production pattern is affected. The proposed explicit method is seen to provide a more focused description of the spatial economic impacts that result from changes in the production of transportation services.

I. Introduction

This study develops an operational interregional computable general equilibrium model, or ICGE, based on a recent large-scale data set of the United States. It differs from other multiregional CGE models in the explicit specification of intra- and interregional transportation and wholesaling services for the flows of goods by sector and origin-destination pair. The study compares the results from this explicit specification with those of a more familiar implicit technique and examines the advantages to be derived from the ICGE method.

ICGE combines the multisectoral CGE heritage of Johansen (1960) with the multiregional spatial modeling efforts dating from Isard's (1951) ideal multiregional input-output model; resulting in a Walrasian price endogeneous, commodity balance model with multiple consumers. This model is solved using a Powell hybrid solution algorithm (NAG 1988) which provides an exact nonlinear solution. Three feedback mechanisms are included in ICGE: the interindustry, interregional, and consumer based multipliers. These occur under conditions of factor substitution, intraregional labor mobility, interregional substitution of goods produced for intermediate input and final consumption, explicit inclusion of transportation and wholesaling services in the spatial movement of goods, and fixed quantities of net international trade.

The full interregional data base was initially assembled by Jack Faucett Associates (1983) for 124 production sectors and for all 50 states plus the District of Columbia. ICGE is developed from a 9-region, 11-sector aggregation of these data provided by the Social Welfare Research Institute (SWRI) at Boston College.

Section 2 provides a brief review of other multiregional CGE models in comparison with ICGE. Section 3 presents the ICGE specification. Section 4 illustrates the sensitivity of ICGE to regionally specific changes in the cost of producing transportation services (based on local productivity gains) through counterfactual scenarios, and compares these results with a model using more implicit means of handling flows. A compact three-region, five-sector model is used for this illustration. The final section discusses the need for additional comparative studies.

II. Previous multiregional CGE models

Although a number of multiregional CGE models have appeared, their approaches and purposes vary greatly. The earliest and most prolific work has been done by the ORANI modelling team in Australia. Through the use of balanced input-output techniques, Dixon et al. (1982) developed top-down estimates of regional effects based on their multipurpose, national-level, Johansen-style CGE model. Recent examples and refinements using this method are discussed in Fraser and Salerian (1987) and Higgs and Powell (1990). Liew (1984) proposed a means of including explicit interregional trade flows in a multiregion model of the ORANI style, but excluded spatial price differentiation or interregional transportation costs. More recently, Higgs et al. (1988) developed a hybrid (top-down, bottom-up) version of ORANI.

A recent nine-region, six-sector tax model of the United States, developed by Morgan et al. (1989), also employs a Johansen-style solution algorithm. Being smaller and less complex than ORANI, it was geared only to questions of regional variations in taxes on input factors. Kimbell and Harrison (1984) also developed a tax model to explore the effects of Proposition 13, using a two-region (California and the rest of the United States) multisectoral framework. This model combines an input-output model for interregional commodity flows with a closed-form tatonnement approach for input factors. It also combines the solution efficiency of linearized models with some of the numerical detail of a Scarf (1967, 1973) style solution. The resultant model does allow for complete mobility and substitution of some factor inputs, but limits interregional commodity flows to fixed coefficients without transportation costs.

Jones and Whalley's (1986) model of Canada is the most sophisticated multiregional model to date and is based on a complete Scarf-style numerical solution algorithm. It includes six regions, thirteen sectors, and a combination of various levels of mobile and immobile input factors. A notable mobile factor is labor, which may change its region of utilization and relocate its consumption to this new location. Because of historical patterns of interregional trade subsidies and tariffs in Canada, the model does not include interregional transportation costs explicitly.

Although the current ICGE is not directly related to any of these earlier models, it most closely resembles that of Jones and Whalley. ICGE includes explicit movement and substitution of commodities (for use both as producer input and as final demand to multiple consumers). It also computes transport and trade services for these movements. In addition, it includes substitution of factor inputs, intraregional mobility of labor, and international trade flows although the latter are restricted to exogenously fixed quantities.[1]

III. The ICGE model

The structure of ICGE is an outgrowth of the single-region work of Dervis et al. (1982). Its spatial detail was developed to utilize the SWRI database, which is a descendant of Leontief's and later Polenske's (1980) collective efforts of operationalizing Isard's multiregional model. The five-sector, three-region model described here represents a skeletal model adequate to investigate questions of explicity versus implicit transportation and trade specifications. It provides the framework upon which a family of more complex models can be built for specific purposes.

Given the circular and simultaneous nature of ICGE, it is best understood by dividing it into four major blocks – production (including factor markets), intra- and interregional trade and clearinghouses, consumption, and balance equations. In solving the model, fixed quantities of factor inputs are sold to the production block where they are combined with intermediate inputs to create regional products. These products are then sent to clearinghouses using transportation and wholesaling services. Each region has clearinghouses, which receive intra- and interregional flows in addition to imports from the rest of the world. Under an Armington (1969) assumption of imperfect substitutes, the clearinghouse provides a convenient, albeit fictitious, construct of the mechanism whereby the same commodity from numerous origins becomes a regionally specific, clearinghouse-composite good. These goods are then made available for either local consumer demand, producer intermediate input, or international export.

At each point where a transfer of mass occurs, payments must flow in the opposite direction. Hence, factor utilization generates income used to pay for consumption and in turn for production and the factor inputs themselves.

The model assumes all markets clear and that labor is intraregionally mobile while capital inputs are fixed by sector and region. This reflects the assumption that, over the medium run, labor can realign itself whereas dedicated capital remains immobile. Two sets of balance equations are used to determine an endogeneous set of factor and product prices and to create a Walrasian mass balance equilibrium.

[1] The version of ICGE reported in Buckley (1988) does allow for interregional movement of labor.

A key difference underlying ICGE is the explicit use of transportation and wholesaling services. Transportation services are required to move goods from a region of production to a clearinghouse at a destination, even if the movement is entirely intraregional. These transportation services are generated only by the region of origin. Wholesale services are also required based on each origin-destination pair, but these are provided by the region of destination.

For the skeletal model there are five policy-based scenarios which can be readily explored. These include changes in (1) production technology, (2) consumption patterns, (3) factor market constraints, (4) net international trade, and (5) intra- and interregional movement technology and networks. Point 5 is highlighted in Sect. 4, where a counterfactual scenario demonstrates the multiregional sensitivity of ICGE to changes in the demand for transportation services. Given this brief description of ICGE's mechanisms, the equations follow.

A. Production

1. Functional forms for production. Three-stage nested Cobb-Douglas/Leontief/Cobb-Douglas functions under constant returns to scale are specified. These are chosen to exploit fully the detail of the SWRI data base and to allow for direct calibration of the model's parameters.[2]

Given that equilibrium models close upon themselves, it may be best to start at Stage 2 with the familiar Leontief level of the production function.

$$SX^s_{i.} = \text{Leontief}\,(X^{\cdot s}_{Ji}, VS^s_i)\ , \tag{1}$$

where $SX^s_{i.}$ is the gross-production by industry i in region s of both a primary product and all secondary by-product outputs, $X^{\cdot s}_{Ji}$ is the vector of intermediate inputs J used by industry i and VS^s_i is the value added services.[3] At this stage each sector concentrates on the production of its primary product, although small amounts of secondary by-products are also produced.

$$X^s_j = \text{Cobb-Douglas}\,(SX^s_{Ij})\ . \tag{2}$$

At Stage 1 regional-composite products X^s_j are generated in each region using Cobb-Douglas functions that combine the primary-product output of an industry

[2] The use of more flexible functional forms would be desireable, but it is impossible to fully calibrate their parameters from the existing SWRI data base.

[3] The notation used in ICGE conforms to the following:

1. Variables are represented by upper case letters.
2. Coefficients are represented by lower case letters.
3. Constants are represented by upper case letters with a bar on top.
4. Superscripts r and s indicate regions, where lower case letters indicate a single region and upper case a vector of all regions.
5. Superscript i and j indicate sectors, with i indicating the primary industry associated with a sector and j the product. In addition t is used to indicate the transportation sector and w wholesaling. Again, lower case is for a single sector/industry/product and upper case for a vector of all possible.

SX_{ij}^{s} (i.e. where i equals j) with secondary by-products of the same output from other industries (i.e. where i does not equal j). This results in five composite products in each of the three regions.

These regional-composite products are then available for utilization, where utilization implies spatial relocation of portions of the regional-composite product to a destination clearinghouse. At the clearinghouse, a vector of intra- and interregional flows of regional-composite product X_j^{Rs} of the same commodity j is combined into a regionally specific clearinghouse-composite good $X_j^{\cdot s}$, where

$$X_j^{\cdot s} = \text{Cobb-Douglas}\,(X_j^{Rs}) \ . \tag{3}$$

These clearinghouse-composite goods are available for use within the region as intermediate inputs or to satisfy final demands.

Finally, value added services VS_i^s (required at the Leontief level of the production function) are generated via the third stage Cobb-Douglas combination of intraregionally mobile labor L_i^s and sectorally fixed capital stocks $\bar{K}_i^s$.

$$VS_i^s = \text{Cobb-Douglas}\,(L_i^s, \bar{K}_i^s) \ . \tag{4}$$

2. *Production prices.* As noted previously ICGE requires the explicit use of transportation and wholesaling services for intra- and interregional flows. As a result, four types of relative commodity prices occur: (1) producers' prices $SP_{i.}^s$, (2) regional-composite product prices P_j^s, (3) clearinghouse-input prices P_j^{sr}, and (4) purchasers' (or clearinghouse-composite-output) prices $P_j^{\cdot r}$.

The producer's price for industry i's gross primary and secondary outputs is determined from the dual Leontief cost function:

$$SP_{i.}^s = \sum_{j=1}^{n} a_{ji}^{\cdot s} P_j^{\cdot s} + VP_i^s \ , \tag{5a}$$

where $P_j^{\cdot s}$ is the purchaser's price for clearinghouse-composite product j, $a_{ji}^{\cdot s}$ is the Leontief intermediate input coefficient, and VP_i^s is the unit cost for value added services for industry i of region s. Thus

$$SP_{ij}^s = SP_{i.}^s \ , \tag{5b}$$

where SP_{ij}^s is the producer's price for commodity j output by industry i.

The prices for regional-composite products are determined from the dual Cobb-Douglas cost functions, based on the combination of primary and secondary production of the same commodity by different industries in a region:

$$P_j^s = \text{Cobb-Douglas}\,(SP_{Ij}^s) \ , \tag{6}$$

where SP_{Ij}^s is a vector of producers' prices for primary or secondary by-product output j.

By adding the unit costs of transportation and wholesaling services for respective origin-destination pairs to the regional-composite prices, spatially differentiated destination prices are generated.

$$P_j^{sr} = P_j^s + t_j^{sr} P_t^s + h_j^{sr} P_w^r \ , \tag{7}$$

where P_t^s is the regional-composite price for transportation services in region s, and t_j^{sr} is the transportation coefficient for moving a unit of j from s to r. Similarly, P_w^r is the price for wholesaling services at destination r, and h_j^{sr} is the wholesaling coefficient for handling a unit of j arriving from s.

Finally, purchasers' prices are determined from the dual cost functions of the Cobb-Douglas specifications (3) used to determine clearinghouse-composite products. Purchasers' prices are the amount paid by all users of a product.

$$P_j^{\cdot r} = \text{Cobb-Douglas}\,(P_j^{Sr}) \ . \tag{8}$$

Note that by rearranging the producer's price equation (5a), it is possible to define the unit cost of value added services as the difference between the producer's price and the summed unit costs of all intermediate inputs. This difference is also commonly referred to as the net price of production NP_i^s.

$$NP_i^s = VP_i^s = SP_{i.}^s - \sum_{j=1}^{n} a_{ji}^{\cdot s} P_j^{\cdot s} \ . \tag{9}$$

The usefulness of this second definition will be apparent later in the discussion of the solution strategy.

3. Factor inputs. In ICGE regional wage rates W^s can be thought of as operating like fixed exogenous variables. However, these prices are actually endogenous variables which are iteratively adjusted using balance equations. As a result, sectoral labor demands L_i^s can be determined by applying Sheppard's lemma to each producer's profit function under conditions of profit maximizing, cost minimizing, and constant returns to scale. The result is

$$L_i^s = (W^s b_i^s / e_i^s NP_i^s)^{-1/f_i^s} \bar{K}_i^s \ , \tag{10}$$

where e_i^s and f_i^s are the Cobb-Douglas coefficients associated with labor and capital, respectively, and b_i^s is the Leontief coefficient for value added services.

In a similar fashion, it is then possible to determine the rental price for immobile capital stocks R_i^s.

$$R_i^s = W^s (f_i^s / e_i^s)(L_i^s / \bar{K}_i^s) \ . \tag{11}$$

B. Consumption and net international trade

1. Consumer income and demand. In the skeletal model, regional income and consumption are handled as total regional returns and demand without differentiation into consuming classes or households. Since the focus of this study is on the interregional flow specification, and not on income distribution between classes, such a simplification seems justified.[4]

Regional income Y^s is defined by returns to all labor utilized in a region, returns to capital stocks owned by local residents, and net gain or loss from international trade. Of these three income generators, capital income is the most complex. Regional returns to capital are based on the total amount of capital owned by residents, the region in which it is employed, and the rental price of capital in that region. Because inexact data exist on exact cross-regional ownership patterns in the United States, the following pattern of ownership is assumed. In regions where consumption exceeds local returns to labor, capital and international trade, it is assumed that residents own additional stock in other regions. After assuming a pattern of maximum local ownership, any "surplus" capital is proportionally divided among other regions indicating ownership of additional capital stocks outside of their borders. The resulting regional income equation is

$$Y^s = \sum_{i=1}^{I} \left(W^s L_i^s + \left\{ \sum_{r=1}^{R} c_i^{sr} R_i^r \bar{K}_i^r \right\} \right) + P_j^s \overline{IE_j^s} \ , \tag{12}$$

where c_i^{sr} is the proportion of capital stock owned by residents of region s employed in industry i of region r, and IE_j^s is the exogenously fixed amount of net international trade of a clearinghouse-composite product.

Consumption is modelled using the linear expenditure system (LES) directly calibrated from the SWRI data[5]

$$D_j^s = \text{LES}\,(Y^s, P_j^s, \bar{M}_j^s) \ , \tag{13}$$

where D_j^s is the demand for clearinghouse-composite j by all consumers in region s, and $\bar{M}_j^s$ is the minimum demand for this same product.

2. Net international trade. International demand is currently handled as exogenously specified quantities of net trade. This is considered adequate 50 long as (1) international trade patterns are not very responsive to change in a counterfactual scenario, (2) production sectors remain highly aggregated, thus masking the impact of a single imported commodity, and (3) net imports for any aggregate commodity are substantially less than the nationally produced clearinghouse total in any region. These assumptions correspond to "large country" trading conditions, where the internal prices are controlled by national market conditions.

[4] Buckley (1988) includes a two class breakdown, and the SWRI (1981) researchers have demonstrated a method of disaggregating to the regional household level through the use of United States Census Bureau data in their input-output study.

[5] As with the production equations, more flexible functional forms, although desirable, cannot be directly calibrated given the data base limitations.

C. Interregional trade and services

1. Tradeable products. Two types of products and accompanying clearinghouses exist in ICGE: tradeable and nontradeable. Clearinghouses for tradeable goods are accumulated from the combination of intra- and interregional product flows, whereas those for nontradeables contain primarily products generated within the region where the clearinghouse is located.[6] The transportation and wholesaling sectors comprise the set of nontradeable goods; i.e., the sectors that effect the movement of most other products across space. All other tertiary services require no movement or handling in order to be marketed outside their region of production.

For tradeable products, the total demand on a regional clearinghouse is madeup of three components: demands for intermediate inputs, consumer final demand, and demand for net international trade.

$$X_j^{\cdot s} = \sum_{i=1}^{I} X_{ij}^{\cdot s} + D_j^{s} + \overline{IE}_j^{s} \ . \tag{14}$$

The intra- and interregional flows into these clearinghouses can be determined by solving input demand functions for the Cobb-Douglas functions (3) underlying the clearinghouse activity, given a set of input destination prices and the total demand on the clearinghouse output.

$$X_j^{rs} = X_j^{rs}(X_j^{\cdot s}, P_j^{\cdot s}, P_j^{Rs}) \ . \tag{15}$$

The summation of these inflow demands across all destinations is the total amount of regional-composite production required by users throughout the nation.

$$X_j^{r\cdot} = \sum_{s=1}^{S} X_j^{rs} \ . \tag{16}$$

2. Transportation and wholesale services for tradeables. The consumption of transport and wholesaling services is accounted for as follows:

$$T^{s\cdot} = \sum_{j=1}^{J} \sum_{r=1}^{R} X_j^{sr} t_j^{sr} \ , \tag{17}$$

where $T^{s\cdot}$ is the total quantity of transportation services required to transport all regional-composite goods originating in region s. Similarly,

$$H^{\cdot r} = \sum_{j=1}^{J} \sum_{s=1}^{S} X_j^{sr} h_j^{sr} \ , \tag{18}$$

[6] Given the arbitrary nature of political boundaries which define the regions, some very tiny flows of nontradeable products are recorded in the SWRI data base.

where $H^{\cdot r}$ is the total quantity of wholesaling services required for goods destined for region r.

Further, these nontradeable services are competitively generated (along with all other goods and services) in the production block. Thus, regions with expanding economic activity face greater competition for scarce factor inputs, and hence higher output prices. Consequently, these same regions will face congestion costs. Such cost increases will act as short-term spatial diseconomies of scale, making exports more expensive and even the internal handling of commodities more costly. On the other hand, regions with decreasing activity will benefit from lower production, transportation, and wholesaling costs, making their exports more competitive.

3. Nontradeable products. The nontradeable sectors, transportation and wholesaling, have two important differences. First, an additional demand is placed on their clearinghouses: the summation of the transportation or wholesaling services required by the tradeable goods. This expands (14) to

$$X_t^{\cdot s} = \sum_{i=1}^{I} X_{ti}^{\cdot s} + D_t^s + \overline{IE}_t^s + T^{s\cdot} \tag{19}$$

and

$$X_h^{\cdot s} = \sum_{i=1}^{I} X_{hi}^{\cdot s} + D_h^s + \overline{IE}_h^s + H^{\cdot s} \ . \tag{20}$$

Second, because there are no transportation or wholesaling marginals associated with these products, the regional-composite price and purchaser's price are identical. For transportation, this means that

$$P_t^s = P_t^{ss} = P_t^{\cdot s} \ . \tag{21}$$

However, flows into clearinghouses are modeled in the same fashion as tradeables using (15) and (16).

D. Balance equations and solution algorithm

Two sets of mass balance equations are currently utilized to close the ICGE. Set 1 deals with regional labor and set 2 with gross-production by sector. The former constraints labor demand to regional supply.

$$\bar{L}^s = \sum_{j=1}^{n} L_j^s \ , \tag{22}$$

where $\bar{L}^s$ is the total supply of labor services in region s. Given estimates of the above mentioned variables, labor demand can be determined by solving the following equations in order: (5b), (6), (7), (8), (21), (9) and (10). Failure of labor demand to balance with supply requires adjustments to the given prices.

The latter set equates two estimates of gross-production by sector. The first estimate is generated by the Leontief functions. Given labor demands as above, optimum allocations of value added services are determined from (4). Based on the Leontief functions (2), gross production by each sector is defined as

$$SX^s_{.i} = VS^s_i b^s_i \ , \tag{23}$$

where b^s_i is the coefficient for services of value added in industry i of region s.

The second estimate is based on the gross-production required to meet the intermediate inputs utilized by the first estimate. This is initiated by determining the sectoral intermediate demands for clearinghouse-composite goods, which are also generated using the Leontief functions.

$$X^{\cdot s}_{ji} = SX^s_{.i} a^s_{ji} \ , \tag{24}$$

where a^s_{ji} is the coefficient for intermediate input j required for gross-production in industry i. The computational process determines consumer income and demand by solving Eqs. (11), (12), and (13) in order. Then it determines regional-composite outputs for tradeable products from (14), (15), and (16). It also executes a similar process for nontradeables using (17, (18), (19), and (20). Finally, it solves the cost minimization functions for the regional-composite production functions (2) to determine the demand for primary and secondary by-product output:

$$SX^r_{ij} = SX^r_{ij}(X^r_j, P^r_j, SP^r_{i.}) \ , \tag{25}$$

where Sx^r_{ij} is an estimate of the primary or secondary output of j from industry i in region r. The second estimate of gross sectoral output $\hat{S}X^r_{i.}$ is then determined from the summation of these demands.

$$\hat{S}X^r_{i.} = \sum_{j=1}^{J} SX^r_{ij} \ . \tag{26}$$

These two estimates of gross sectoral production are then compared:

$$\hat{S}X^r_{i.} = SX^r_{i.} \ . \tag{27}$$

Their convergence is obtained by iterative adjustments $SP^r_{i.}$ and W^r. In summary, given a set of 48 constants and initial estimates for the 18 iteratively adjusted endogenous price variables, the solution proceeds by algebraically determining 417 additional price and quantity variables that are needed to define the 18 balance equations. Because the model is over-identified, the regional wage rate in region 2 is set to one.

IV. Comparison of ICGE with an implicit method

A. The implicit model

To explore the ramifications of the explicit specifications of handling and movement used in ICGE, in this section it is compared with an implicit method. The latter approach is similar to Round's (1988) proposed means of including transfer costs in interregional social accounting matrices. In this case, transportation and wholesaling services are treated as commodities that can be directly consumed, traded or substituted interregionally. This requires two alterations to the original ICGE structure. On the production side, transportation and wholesale services are handled as direct intermediate inputs rather then origin-destination based marginals. For transportation, this is done by using the clearinghouse Cobb-Douglas functions to combine the transportation services from all origins to a given destination – thus creating a clearinghouse-composite. Next, intermediate demands are determined for portions of these services using the Leontief form of the production functions (24). This results in continued utilization of transportation services from all regions, but the quantity demanded is no longer directly linked to the flow of tradeable products. Wholesaling is handled in a similar fashion, although little interregional trade is required since wholesaling is primarily produced in the region of use.

On the final demand side, the implicit approach exhibits even fewer linkages. Consumers and exporters are now required to distinguish direct purchases of clearinghouse-composites of transportation and wholesaling from purchases of tradeable products. This again replaces the use of marginals. In addition, consumer use of transportation for freight and for personal mobility is combined into one final demand item. In summary, the implicit approach creates a type of "production price" model rather than the explicit "consumer price" model.

The base cases for both specifications are calibrated using a three-region, five-sector agglomeration of the SWRI data (Table 1). However, these two base cases do not produce identical results, highlighting basic differences between the

Table 1. Model regions and sectors

Region	U.S. Census Bureau Geographic Regions
1. North	Northeast, Middle Atlantic, East North Central, West North Central
2. South	South Atlantic, East South Central, West South Central
3. West	Mountain, Pacific
Sector	**Abbreviation**
1. Primary Industries	PRIMARY
2. Secondary Industries	MANUFAC
3. Tertiary Industries	SERVICE
4. Transportation Services	TRANS
5. Wholesaling Services	WHOLE

approaches. A listing of the variables and constants which coincide or differ may be found in Appendix I. Flows out of the clearinghouses, demands for intermediate inputs, and quantities of consumer goods and exports are all different. This is despite the fact that total regional incomes and regional expenditures on net international trade remain the same. An even more important difference, not noted in Appendix 1, is that both the Paasche and Laspere measures of utility are different for each of the two base cases (for this example, the size of the variation is nearly 5%). The primary cause of this difference is the utilization of nonlinear functions in ICGE. As a result, purchasers' prices in the implicit model are not a linear variation of the same prices in the explicit model. When these prices are later used in the calibration procedure to determine the quantity of goods consumed for the two base cases, the aggregate units of measure calibrated for each model differ. This difference confirms the fact that even though both models are calibrated from the same data set they are structurally different.

Given these basic differences, the next step is to investigate how such differences affect their operation when the models are utilized in counterfactual scenarios. Space limitations permit the presentation of only a single comparison, which focuses on a change in factor productivity. This scenario was chosen to provide a highly transparent illustration of how the two models vary. A more complex scenario could easily produce greater variations between the two methods, but might be difficult to comprehend.

B. Comparison using a counterfactual scenario

The counterfactual scenario investigates the impact of an increase in factor productivity in the transportation sector of one region, leading to a lower demand for value added services per unit of output. This is accomplished by merely adjusting downwards the Leontief coefficient in (23) and, given fixed capital stocks, results in more intensive and efficient use of labor. For the scenarios, this coefficient is decreased by 50% for transportation services in region one; other regions' coefficients remain as in the base case.

Some of the scenario results are presented in Appendix 2 (for regions 1 and 2). Changes are measured in relationship to each model's base case, with unit wages in region 2 serving as a numeraire.

1. ICGE *explicit method results.* Greater labor productivity in the transportation sector in region 1 leads to a decrease in transportation costs both for internal movement of locally produced tradeables and for interregional exports. This results in competitively lower destination prices for tradeables from region 1, which replace higher priced outputs from regions 2 and 3. This higher demand leads to increased production (1.7%) in the primary and secondary sectors in region 1, and slight decreases in the other two regions. An additional cause of lower cost outputs from region 1 is that labor is released from the transportation sector (−55.2%) because of the productivity gains, enabling it to move to other sectors in the region.

Overall production increases in region 1 but changes little in region 2. Outflows of PRIMARY and MANUFAC products generated in region 1 increase (for example PRIMARY products jump by 1.8% to region 2 and 3.4% to region 3), while the only increase in region two is of PRIMARY output destined for use in region 1 (0.5% increase). This latter increase follows from the greater activity in region 1.

The 8.9% increase in production of transportation services in region 1 is primarily due to a much greater consumer demand for personal travel (57.4%). Regional consumer demand grows at similar rates in each sector except for transportation.

2. *Implicit method results.* Because transportation appears as an interregionally traded commodity in this approach, its lower price in region 1 promotes its use instead of transportation produced elsewhere. The result is a marked increase of transportation services in region 1 (34.7%), outscoring decreases in regions 2 and 3 (−5.5% and −4.9%, respectively). The outcome is a lower end-user's price of transportation services throughout the nation (−37.0% in region 1 and −11.5% in region 2), and surplus labor from the transportation sector in all regions (−40.7% and −7.1% respectively in regions 1 and 2). Thus all regions increase production in all sectors except transportation and trade between all regions increases. In reality, however, indigenous transportation services within and between regions 2 and 3 do not experience any direct productivity gains. The outcome is that fewer transportation services handle more goods in these regions.

3. *Comparison.* Based on the above remarks, the advantages of the explicit ICGE method seem to be threefold. First, the direct linkage of movement and handling services to the actual products moved prevents over/under production of these services by region. Second, end users of the products purchase a correct amount of these services for delivery of their bundle of goods. Finally, since the explicit method limits consumer final demand to transportation for personal mobility, a much clearer picture of consumption emerges. Thus the explicit method provides a spatially focused method of understanding changes in the transportation and wholesaling sectors.

V. Conclusions

CGE models, especially multisectoral and multiregional ones, are sensitive to the manner in which they are specified. Given the small amount of data required to calibrate such models, more than one structure might easily be derived from the same data set(s). This has been recognized in the macroeconomic rules of closure (Taylor 1983). Questions surrounding the intra- and interregional flow of commodities, and the inclusion of services to carry such commodities across space, offer another challenge. Round (1988) has recently detailed the need to include such information in data collection efforts. The current study suggests that careful attention should also be paid to the specification chosen, which in turn can determine how the data are collected and organized.

From the scenarios summarized in this paper, it is evident that a different pattern of regional production activity emerges from an explicit formulation of their use rather than an implicit one.

Appendix 1

Comparison of constants and variables for the base cases of ICGE *and the implicit modeling method*

Identical in both	Different in each
I. Constants	
$\bar{L}^s \bar{K}_i^s$	$\overline{IE}_j^s \bar{M}_j$
II. Iteratively determined endogenous price variables	
$SP^s W^s$	
III. Algebraically determined endogenous variables	
1. Commodity price estimates	
$P_j^s NP_i^s$	$P_j^{sr} P_j^{\cdot r}$
2. Factor demands and prices	
$L_i^s R_i^s VS_i^s$	
3. Consumer income and demand	
Y^s	D_j^s
4. Gross-production and intermediate input demand	
$SX_{i.}^s$	$X_{ji}^{\cdot s}$
5. Tradeable products	
$X_j^{rs} X_j^r$	$X_j^{\cdot s}$
6. Nontradeable products	
X_j^r	$T^{s\cdot} H^{\cdot r} X_t^{\cdot s} X_w^{\cdot s} X_j^{rs}$
7. Primary and secondary outputs	
SX_{ij}^s	

Appendix 2

Scenario comparison of explicit ICGE *with implicit specifications*
A. Producer activity

Sector	% Change in units		% Change in price	
	Explicit scenario	Implicit scenario	Explicit scenario	Implicit scenario
Region 1				
PRIMARY	1.7	0.8	0.8	−0.3
MANUFAC	1.7	1.1	−1.1	−1.1
SERVICE	0.5	0.6	−0.9	−0.7
TRANS	8.9	34.7	−37.0	−34.4
WHOLE	1.3	1.1	−1.4	−1.2
Region 2				
PRIMARY	−0.0	0.2	−0.4	−0.1
MANUFAC	−0.0	0.2	−0.4	−0.4
SERVICE	0.1	0.1	−0.2	−0.2
TRANS	0.0	−5.5	−0.3	−2.5
WHOLE	0.0	0.2	−0.3	−0.4

B. Interregional trade comparison for PRIMARY product

	% Change in units		% Change in destination price	
Destination region	Explicit scenario	Implicit scenario	Explicit scenario	Implicit scenario
Origin region 1				
1	1.7	0.9	−1.6	−0.3
2	1.8	0.4	−2.3	−0.3
3	3.4	0.3	−3.7	−0.3
Origin region 2				
1	0.5	0.6	−0.5	−0.1
2	−0.1	0.1	−0.4	−0.1
3	0.0	0.0	−0.4	−0.1

C. Interregional trade comparison for TRANS product

Destination region	% Change in units		% Change in destination price	
	Explicit scenario	Implicit scenario	Explicit scenario	Implicit scenario
Origin region 1				
1	38.0	32.0	−37.0	−34.4
2	0.0	43.7	–	−34.4
3	0.0	44.0	–	−34.4
Origin region 2				
1	0.0	−11.2	–	−2.5
2	0.2	−4.0	−0.3	−2.5
3	0.0	−3.1	–	−2.5

D. Labor

Sector	% Change in units	
	Explicit scenario	Implicit scenario
Region 1		
PRIMARY	6.2	2.9
MANUFAC	2.4	1.6
SERVICE	0.9	1.1
TRANS	−55.2	−40.5
WHOLE	2.1	1.7
Region 2		
PRIMARY	−0.2	0.7
MANUFAC	−0.0	0.3
SERVICE	0.1	0.2
TRANS	0.0	−7.1
WHOLE	0.0	0.3

E. Consumer activity

Sector	% Change in units		% Change in price	
	Explicit scenario	Implicit scenario	Explicit scenario	Implicit scenario
Region 1				
PRIMARY	0.5	−0.4	−1.4	−0.3
MANUFAC	0.9	0.3	−1.8	−0.1
SERVICE	−0.0	0.0	−0.9	−0.7
TRANS	57.4	39.8	−37.0	−29.0
WHOLE	0.5	0.5	−1.4	−1.2
Region 2				
PRIMARY	0.6	0.1	−0.6	−0.1
MANUFAC	0.9	0.5	−0.9	−0.5
SERVICE	0.3	0.2	−0.3	−0.3
TRANS	0.3	13.0	−0.3	−11.5
WHOLE	0.4	0.4	−0.4	0.4

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