Handbook of Regional Growth and Development Theories

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21 Modern regional input–output and impact analyses

Jan Oosterhaven and Karen R. Polenske

21.1 Introduction

Economic impact analysis has a long tradition in the input–output (IO) field. A search on Google in May 2007 for impact analyses and IO models produced 1 090 000 records. Many were undoubtedly duplicates or referred to only one or the other of these terms, but we were nevertheless impressed with the proliferation of this technique. Of the various applications of IO models, impact analysis is undoubtedly the most widely used. Many of the early applications estimated economic impacts, but soon analysts were also studying environmental, energy, transportation, land-use and other types of impacts, and these have proliferated greatly beginning in the 1990s. With the recognition of the important worldwide climate change effects, we anticipate that analysts will conduct even more environmental- and energy-impact studies than before.

Underlying the regional analyses is the important basic theory of input–output and socio-economic accounting. We begin by reviewing this basic theory in terms of some of the significant methodological debates that occur. Although not all developments are region-specific, we cover them because regional analysts are beginning to adopt these theoretical advancements in their work. For the applications, we restrict our review to regional and multi-regional impact analyses and the development of computer programming packages that help analysts to conduct such studies quickly.

21.2 Theory of demand-driven IO and SAM impact analysis

One of the most frequently heard criticisms of IO analysis concerns the assumption that the input–output coefficients are constant. By making this assumption, Leontief was able to use data over ten-year and longer periods. Early tests by Carter (1970) and Vaccara (1969) using US national input–output tables for 1939–60 showed that this was not an unrealistic assumption, and Carter (1970) and Strout (1967) found that good output estimates could be achieved by making changes in the input coefficients for only selected sectors, such as chemicals and energy, respectively,

Those of us working at the regional scale, due to lack of data, often had to assume that the national and regional technologies were identical. This seemed less realistic, due to regional product-mix and price differences, than to assume that the actual technology remained constant over time. Rather than to develop new theoretical models to take account of economic geography and spatial accessibility differences, early US regional analysts initially used surveys to obtain the data required for the regional IO tables. By the 1980s, as funding became limited, they devised non-survey methods to estimate regional IO tables, based upon either national technologies or upon regional technologies from a different region. Only since 1990 have new spatial economic theories begun to surface for use with the regional economic impact models. As we show later, the current regional socio-economic impact analysts are building models to account for changes in both technological and interregional trade relations, thus bringing economic geography theories into prominence.

In practice, non-survey, symmetric IO table (IOT) construction is closely connected with IO model building. In theory, however, they relate to two different operations. Most data construction assumptions use uniform distributions to fill in lacking data in absence of real data. Even when analysts use non-linear gravity- or entropy-maximizing assumptions to construct interregional IOTs (Oosterhaven, 1981a, Appendix; Batten, 1983), their aim is to come as close to the lacking data as possible. The same holds when they use 'industry technology' or 'commodity technology' assumptions to construct symmetric industry-by-industry or commodity-by-commodity IOTs from supply and use tables (Kop Jansen and ten Raa, 1990; ten Raa and Rueda-Cantuche, 2003).

These data construction assumptions differ from the theoretically based behavioral assumptions of fixed intermediate input ratios a_{ij} and fixed primary input ratios c_{kj} used in IO modeling. Notwithstanding the information on changes in these ratios over time, analysts still commonly assume them to be constant when modeling the future or when estimating impacts of specific exogenous changes with the Leontief model. One main justification is that, for closed economies, the analyst can theoretically derive fixed ratios by assuming profit-maximizing firms that produce total output x_j with a Walras–Leontief production function under constant returns to scale:

$$x_j = \max\left(z_{ij}/a_{ij}, \text{ with } i = 1, \ldots, I,\ v_{kj}/c_{kj}, \text{ with } k = 1, \ldots, K\right), \tag{21.1}$$

and that firms sell this output on markets with full competition. This combination of assumptions assures that, irrespective of the relative prices of intermediate and primary inputs, cost minimization with a given total output x_j always leads to fixed input ratios and to the well-known IO demand functions for intermediate and primary inputs:

$$z_{ij} = a_{ij}\, x_j \text{ and } v_{kj} = c_{kj}\, x_j \quad \text{or in matrix notation: } \mathbf{Z} = \mathbf{A}\,\hat{\mathbf{x}} \text{ and } \mathbf{V} = \mathbf{C}\,\hat{\mathbf{x}} \tag{21.2}$$

where $\hat{\mathbf{x}}$ denotes a diagonal matrix, and where the combined column sum of **A** and **C** equals one, that is, $\mathbf{i}'\,\mathbf{A} + \mathbf{i}'\,\mathbf{C} = \mathbf{i}'$. Note that equation (21.2) implies full economic complementarity of all inputs.

Adding the definition of total demand and assuming that the supply of output always follows total demand gives:

$$x_i = \Sigma_j\, z_{ij} + \Sigma_q f_{iq} \text{ or in matrix notation: } \mathbf{x} = \mathbf{Z}\,\mathbf{i} + \mathbf{F}\,\mathbf{i} \tag{21.3}$$

Solving equations (21.2)–(21.3) for exogenous final demand $\mathbf{f} = \mathbf{F}\,\mathbf{i}$, leads to the well-known solution of the IO model for any aggregate impact variable v, such as total regional or national value-added, employment, energy use or CO_2 emissions:

$$v = \mathbf{c}'\,\mathbf{x} = \mathbf{c}'\,(\mathbf{1}-\mathbf{A})^{-1}\mathbf{f} \tag{21.4}$$

in which **c'** indicates a row with value-added, employment, energy use, or CO_2 emission coefficients per unit of output. Note that equation (21.3) also implies that any exogenous or endogenous change in demand is fully met by the appropriate supply of intermediate and primary inputs. Analysts who use the standard IO model thus assume that there are no supply restrictions. Therefore this IO model is best labeled as a demand-driven quantity model.

This foundation of equation (21.4) in production theory becomes insufficient if we move from a closed economy to an open economy. Consider the closed world economy as a system of R open regional economies, then (21.4) mathematically also describes the interregional IO model (Isard, 1951) as well as the multi-regional IO model (Chenery, 1953; Moses, 1955; Polenske, 1980), but then the vectors **c**, **x** and **f** all have dimension IR and the matrices **I** and **A** have dimension IR x IR. The most important difference with the closed economy model is that the intermediate input coefficients now also get two dimensions:

$$\text{interregional IO model: } a_{ij}^{rs} = t_{ij}^{rs} a_{ij}^{\cdot s} \qquad \text{multi-regional IO model: } a_{ij}^{rs} = t_{i\cdot}^{rs}\, a_{ij}^{\cdot s} \tag{21.5}$$

with the · indicating the summation over the relevant index. Equation (21.5) explicitly shows that the interregional and the multi-regional input coefficients a_{ij}^{rs} represent the product of real technical coefficients $a_{ij}^{\cdot s}$ from production function (21.1), and cell-specific *trade* coefficients t_{ij}^{rs} in the case of the interregional input–output (IRIO) model, or (row) aggregate trade coefficients $t_{i\cdot}^{rs}$ in the case of the MRIO model. In the case of the single-region IO model, the intra-regional trade coefficients t_{ij}^{rr} and $t_{i\cdot}^{rr}$ are better known as, respectively, cell-specific or aggregate, self-sufficiency ratios or regional purchase coefficients (RPCs; Stevens and Treyz, 1986).

The theoretical foundation for assuming the trade coefficients to be fixed is less convincing than that for the technical coefficients. The analyst may assume that the output of, for example, agriculture is a different product in each different region. The trade coefficients will then get a technical character and will be fixed for the same reasons as the technical coefficients. As each cell then relates to different goods, this assumption fits best with the IRIO model. The analyst may also assume that the products of, again for example, agriculture in different regions are close substitutes for each other. The trade coefficients will then only be fixed for as long as the relative prices of agricultural output from different regions remain unchanged. As relative prices will influence all trade coefficients along a row of the IO table in the same manner, this assumption fits best with the MRIO model.

In interregional impact studies, equation (21.4) is disaggregated by regions to allow for the separate estimation of intra-regional impacts and interregional spillover effects (Miller and Blair, 1985). When intra-regional impacts from the single-region model are compared with those from the interregional model, the latter will be larger. This difference is caused by interregional feedback effects. These link the imports of the home region to the output levels of other regions, which are linked back to the intermediate exports of the home region. As a consequence, exogenous final demand will be smaller than in the single-region model, as the export of intermediates becomes endogenous. Of course, when the smaller exogenous final demand is multiplied by the larger multipliers that include the interregional feedbacks, the resulting endogenous employment and value-added will be the same. Interregional feedbacks are found to be relatively large (5–15 percent) for regions within well-integrated large conurbations and smaller (<5 percent) for relatively isolated regions (Oosterhaven, 1981a).

The size of the feedbacks and this difference become larger when the standard IO model is extended with a consumption function for labor incomes, as labor incomes earned in the home region will spill over into other regions and feed back into the home region through the additional mechanisms of interregional commuting and interregional shopping (Madsen and Jensen-Butler, 2005). There is a whole family of demo-economic extensions of the basic Type I model into Type II, III, and so on, regional IO models (Batey, 1985). However, the important distinction between increases in labor incomes accruing to resident workers (intensive income growth), new labor incomes accruing to migrants and unemployed (extensive income growth), and the loss of benefits of formally unemployed (redistributive income growth) can only be modeled properly if levels of economic activity are explicitly distinguished from changes therein (Oosterhaven and Folmer, 1985).

With levels and changes in levels distinguished, the interregional Type III variant of equation (21.4) becomes:

$$\Delta v = \mathbf{c'}\,\Delta\mathbf{x} + \Delta\mathbf{c'}\,\mathbf{x}_{-1} = \mathbf{c'}\,(\mathbf{I} - \mathbf{A} - \mathbf{Q_w}\,\mathbf{W}\,\hat{\mathbf{c}}_\mathbf{w} + \mathbf{Q_u}\,\mathbf{U}\,\hat{\mathbf{c}}_\mathbf{u})^{-1}\,\Delta\mathbf{f} + \Delta\mathbf{c'}\,\mathbf{x}_{-1} \qquad (21.6)$$

If Δv represents, for instance, the system-wide change in employment, $\Delta\mathbf{c'}$ represents the *IR*-row with decreases in employment coefficients due to nominal labor productivity increases, and $\mathbf{x}_{-1}$ represents the output impact of the combined lagged endogenous and exogenous variables. Furthermore, $\mathbf{Q_w}$ and $\mathbf{Q_u}$ represent the consumption expenditure on products from sector i in region r, respectively, per working resident and per unemployed resident in region s. The interregional diagonal blocks of $\mathbf{W}$ (with $\sum_r w_j^{rs} = 1$) represent the shares of the new jobs in sector j in region s directly or indirectly taken up by residents of region r, and the comparable blocks of $\mathbf{U}$ (with $\sum_r u_j^{rs} < 1$) represent the shares of the new jobs in sector j in region s directly or indirectly taken up by residents of region r that were formally unemployed. Finally, the diagonal matrices $\hat{\mathbf{c}}_\mathbf{w}$ and $\hat{\mathbf{c}}_\mathbf{u}$ represent the per unit labor incomes and the per unit lost unemployment benefits, respectively. Typically, $\mathbf{W}$ and $\mathbf{U}$ are determined by means of an IO vacancy-chain sub-model. With the unemployment benefits of the Netherlands, Type III impact multipliers $\mathbf{c'}(\mathbf{I} - \mathbf{A} - \mathbf{Q} + \mathbf{Q}^\mathbf{u})^{-1}$ from equation (21.6) move between 35 percent and 60 percent of the difference between Type I multipliers $\mathbf{c'}(\mathbf{I} - \mathbf{A})^{-1}$ and Type II multipliers $\mathbf{c'}(\mathbf{I} - \mathbf{A} - \mathbf{Q})^{-1}$ (van Dijk and Oosterhaven, 1986).[1]

The distinction between demo-economic models and social accounting models (SAMs) is not large in the sense that a SAM may be interpreted as a demo-economic model with a more elaborate disaggregation of the household sector. It is, however, more fundamental in that SAMs invariably start with defining the underlying accounting framework explicitly, and then derive their impact multipliers more or less directly from it. Pyatt (2001) uses this approach to show that sectorally and regionally disaggregated Keynesian income multipliers (Miyazawa and Masegi, 1963; Miyazawa, 1976) can be viewed as special cases of various SAM multipliers (Pyatt and Thorbecke, 1976; Pyatt and Round, 1979). The core difference is that Miyazawa multipliers relate the factor (capital versus labor) generation of income by sector and region, directly to the spending of that income on products from different sectors and regions. SAM multipliers are more general in that they add the redistribution of income by different institutions in-between the generation and the spending of income to the IO model. As a consequence, SAMs are better suited to study the impact of policy instruments on the distribution of income and poverty.

The obvious next question is: how far should an analyst endogenize the various components of final demand? Studying the regional impacts of plant close-downs with a SAM, Cole (1989, 1997) advocates the fullest possible closure of the single-region model to capture all possible short- and long-run impacts. Government expenditure is made dependent on tax income, investment expenditure on the operating surplus, and regional exports on regional imports. This led to a major debate with Jackson et al. (1997) about zero exogenous demand and infinite multipliers, which was concluded by Oosterhaven (2000). Analysts cannot endogenize interregional feedbacks consistently without specifying the full interregional model, in which case the full closure of the rest of the model indeed results in zero exogenous demand. As a consequence, such a SAM may no longer be used to evaluate the impacts of changes in demand, because these have become endogenous.

The danger of overestimating impacts also occurs when total value-added or employment of an existing firm or sector is multiplied by that firm's or sector's Type II normalized value-added or employment multiplier, $\mathbf{c}' (\mathbf{I} - \mathbf{A} - \mathbf{Q})^{-1} \hat{\mathbf{c}}^{-1}$, to indicate its economic importance for the economy at hand. Of course, this is a misuse of impact analysis for public-relations purposes. Formally, an analyst may only multiply an IO multiplier by exogenous final demand and never by endogenous value-added or employment. Imagine that the average normalized employment multiplier equals 2 and that the analyst would apply this way of estimating the impact to all sectors; then, the predicted size of the total economy would be twice its actual size. One solution is to correct the calculated 'gross impact' of a certain sector with the part of that sector that is endogenously dependent on the rest of the economy in order to obtain the net impact of that sector (see Oosterhaven et al., 2003, for energy distribution). A second solution is to define a net multiplier that may be multiplied with a sector's total employment or output, such that the weighted average of all sectors' net multipliers equals one (Oosterhaven and Stelder, 2002).[2]

More generally, the fullest possible closure of standard IO models exacerbates the theoretically already problematic one-sidedness of that model. Possible shortages on local labor markets, price and wage reactions, and the pressure to develop new markets and new products will, for example, reduce the demand-driven quantity impact of a plant close-down. In such cases, endogenizing price effects and supply reactions may be more important than a full closure of the demand side, that is, if analysts are interested in the best estimate of the real impacts instead of maximum multipliers.

21.3 Theory of price and supply-side impact analysis

An analyst may use the less well-known dual of the Leontief model to estimate endogenous output price impacts $\mathbf{p}$ of the exogenous primary input prices $\mathbf{p}_v$ (Leontief, 1951). The dual, however, cannot be used to model the effects of price changes on quantities, as follows from the solution of the standard (Type I) price model (Schumann, 1968):

$$\mathbf{p}' = \mathbf{p}_v' \, \mathbf{C} \, (\mathbf{I} - \mathbf{A})^{-1} \tag{21.7}$$

In equation (21.7), the K exogenous, capital, labor, and import price changes $\mathbf{p}_v$ are directly passed on via $\mathbf{C}$ into output price changes, and are then indirectly carried forward further via the rows of $\mathbf{A}$ into equilibrium total output price changes. Therefore, equation (21.7) is best characterized as a cost-push price model.

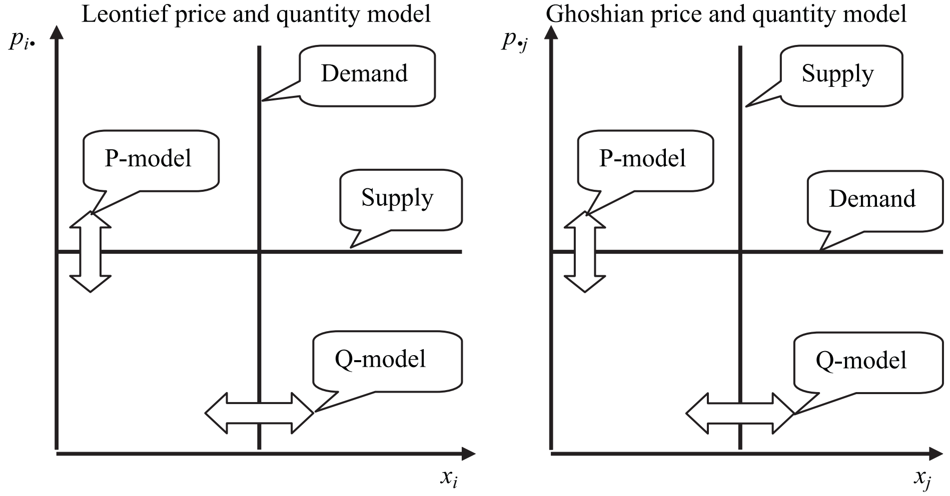

Figure 21.1 The functioning of markets in Leontief and Ghoshian IO models

In the left-hand panel of Figure 21.1, we show the relationship between the demand-driven quantity model and this cost-push price model for an individual IO market. The demand curve (driven by the quantity model) shifts left and right along the perfectly elastic supply curve (no shortages). Independently, the supply curve (driven by the price model) shifts up and down along the perfectly inelastic demand curve. This IO price model, *inter alia*, has been used to estimate the price effects of pollution abatement (Giarratani, 1974) and the effects of energy price rises in a multi-regional input–output (MRIO) model (Polenske, 1979).

When the interregional quantity model is extended with a consumption function for labor incomes, its dual price model of course changes analogously. Wages become endogenously determined by the prices of consumption goods, and the remaining exogenous primary input prices get multiplied with larger Type II cost-push multipliers resulting in the same equilibrium prices for total output (see Oosterhaven, 1981b, for interregional wage and price impacts of the oil price hike).

Also disregarding the price-induced impact of supply on demand, Giarratani (1976), Davis and Salkin (1984) and Chen and Rose (1985) have used the supply-driven IO model, developed by Ghosh (1958), as a direct way to model the impacts of natural resource shortages on output. In every respect, this quantity interpretation of the Ghosh model represents the pure opposite of the demand-driven quantity model, as follows from its solution for endogenous final demand (Oosterhaven, 1996):

$$\mathbf{F} = \hat{\mathbf{v}}\,(\mathbf{I} - \mathbf{B})^{-1}\,\mathbf{D} \tag{21.8}$$

In equation (21.8), exogenous primary supply $\hat{\mathbf{v}}$, without further need of intermediate inputs, directly leads to equally large total inputs $\hat{\mathbf{x}}$ (the direct forward effect), which is distributed to purchasers according to *IxI* fixed intermediate output coefficients, $b_{ij} = z_{ij}/x_i$, and *IxQ* fixed final output coefficients, $d_{iq} = f_{iq}/x_i$. The intermediate outputs, without further need of primary or intermediate inputs, lead to equally large total inputs (the first round indirect forward effect), which are again distributed to intermediate and final purchasers according to **B** and **D**, and so on.

Originally, Ghosh formulated his model not in terms of quantities, but in terms of values. Dietzenbacher (1997) proved that a value interpretation can be formulated such that it is equivalent with the Leontief cost-push price model. Quantities remain unaffected, and analysts may evaluate final output price impacts of exogenous primary input prices in terms of values instead of in terms of prices. With this interpretation, the row sums of the Ghosh-inverse $(\mathbf{I} - \mathbf{B})^{-1}$ may still be used as a descriptive statistic, measuring the size of a sector's forward linkages, just as the column sums of the Leontief-inverse $(I - A)^{-1}$ are used to measure the size of the backward linkages.

After the criticism by Oosterhaven (1988), the quantity interpretation of the supply-driven IO model is no longer used, as it theoretically allows cars to drive without gasoline and factories to work without labor. Only by intelligently combining processing coefficients (= inverses of the technical coefficients $a_{ij}^{\cdot r}$ and $c_{kj}^{\cdot r}$) with intermediate output or allocation coefficients (b_{ij}^{rr}), while adapting regional purchase coefficients ($t_{i\cdot}^{rr}$) to accommodate for import and export substitution (Oosterhaven, 1988), may the forward effects idea of the supply-driven IO model still be used (see Cartwright et al., 1982, for a nuclear disaster application, and Oosterhaven, 1981a, for a land-reclamation application).

Interestingly, the dual of the Ghosh quantity model (Davar, 1989) has not been used for price impact studies yet, whereas this is clearly possible, as follows from its solution:

$$\mathbf{p} = (\mathbf{I} - \mathbf{B})^{-1}\,\mathbf{D}\,\mathbf{p_f} \tag{21.9}$$

In equation (21.9), the Q prices for each column with homogenous final inputs ($\mathbf{p_f}$) are exogenous, whereas the I prices for each column with homogenous sectoral inputs ($\mathbf{p}$) are endogenous. Any increase in, for example, the unit price for exports p_q leads to a direct increase in the unit revenues of each sector i with $d_{iq}\,p_q$. Under full competition this increase is entirely passed on into the price of the single homogenous input of sector i. In the next round, this price increase leads to an increase in the unit revenues for all sectors j with $b_{ji}\,p_i$, which is further passed on again via **B**, and so on. Naturally this model may best be characterized as the demand-pull price model.

The right-hand panel of Figure 21.1 shows how the Ghoshian price and quantity model 'interact'. In the quantity model, the supply curve shifts left and right along a perfectly elastic demand curve, not causing any price reaction (consumers consume whatever is supplied at the going price). Independently, in the price model, the demand curve shifts up and down along the perfectly inelastic supply curve, not causing any quantity reaction. According to Oosterhaven (1996) the demand-pull price model is less implausible than its companion supply-driven quantity model. But it is clear from Figure 21.1 that the more plausible Leontief price and quantity model also may be labeled as 'special'.

In fact, both sets of IO models represent extreme cases of the general equilibrium model. Clearly, implementing the latter model at the combined inter-sectoral and inter-regional level is more complicated and far more data-demanding than the comparable IO model. For this reason, most developments in impact analysis seek to modify the basic Leontief model by introducing more flexible (for example translog) production functions for capital, labor, and intermediate input (for example the KLEM production function, that is, Kapital Labor Energy and Materials), and by introducing econometrically estimated consumption, investment and export functions, while sticking to the Leontief specification for the matrix of intermediate demand only.

21.4 Developments in IO data construction and model applications

Spatially, analysts have constructed both regional and multi-regional IO impact models.

Regional IO table construction and applications

At a regional scale, we have progressed relatively slowly from the initial impact studies, which included Moore's (1955) classic article on 'Regional economic reaction paths', to the well-explained inter-industry model for Utah by Moore and Peterson (1955), in which they used a supply-demand pool procedure to estimate the regional transactions, to Hirsch's (1959) St Louis model for which he collected data from company records and built a detailed export sector. Miernyk's work in the nine Colorado river basins (with Udis), and in the state of West Virginia, certainly contributed greatly to the collection of regional data through surveys in the United States. In his easy-to-read book *The Elements of Input–Output Analysis* Miernyk (1965) gave many useful guidelines for survey design and model building, including how to select 'best-practice' (most technologically advanced) firms. He also started the use of the terms 'Type I' and 'Type II' multipliers. The most extensive and longest-lasting collection of regional data through surveys is by the Washington State researchers in a tradition dating back to 1963 and continuing to today.[3] That state table is used as the standard by many US regional analysts.

Since the 1970s, most IO tables for other US regions have been estimated using various short-cut techniques, such as multiplying national technical coefficients by regional location quotients, primarily because of the high costs involved in conducting surveys. These non-survey techniques, however, produce relatively inaccurate regional tables (see Polenske, 1997, for an evaluation). Moreover, by using location and other quotients, most methods implicitly maximize intra-regional transactions and minimize regional imports in one way or another. Consequently, all regional multipliers from such tables have a systematic upward bias, even when analysts claim that there is relatively little cross-hauling (as West, 1990, p. 108, does for Australia). In more densely populated and diversified economies, however, cross-hauling is the rule, even more so when commuting across regional boundaries is important and Type II multipliers are concerned (Oosterhaven, 1981a).

Many US regional analysts use the Washington State table either to create input–output tables for their own region or to test for differences in the national and state coefficients. Analysts could reduce errors to less than 10 percent only by sectoral aggregation or by using exogenous information on more than 60 percent of the non-zero cells (Polenske, 1997). The latter observation stresses the conclusion of Lahr (1993) that hybrid methods should be preferred to simple non-survey methods.

A hybrid Dutch regional IO table, for example, resulted from a survey into four tourist-specific branches in the province of Drenthe. The survey regional import coefficients of the tourist branches were applied to the national technology coefficients for the other sectors. The complete IO table resulted by combining the survey and non-survey columns into a single table. A comparison with the multipliers from a survey-based bi-regional table showed differences in the indirect part of the tourist branches' multipliers of only 5–10 percent, whereas the differences in the indirect parts of the other multipliers ran from –50 percent to +65 percent, with some outliers beyond that (Spijker, 1985). We believe that this shows that both Bourque (1990) and Beemiller (1990) are right in their discussion in the *International Regional Science Review*; Bourque in his rejection of RIMS's non-survey alternative for the Washington State IOT and Beemiller in his claim that combining direct information for the sectors of an impact study with a non-survey IOT produces sufficiently accurate estimates for most practical impact questions.

The Washington State IO model is widely used for a diverse set of economic impact analyses. Bill Beyers, for example, used it to estimate the economic impacts of arts and cultural organizations on the Washington economy; the impacts of building and operating the new Seattle symphony hall; the impacts of the Mariners Baseball Team; and those of the Fred Hutchinson Cancer Research Center. As indicated above, the Washington IOT is extremely well known among US regional planners, many of whom have used it to calculate the accuracy of their own tables, and/or to estimate state tables based upon the Washington State table.

For the United States, two options seem relevant. First, regional technologies are sufficiently diverse that regional analysts should be arguing for funds to conduct surveys to derive their tables based upon actual data for that region. Second, analysts should be devising new methods of estimating regional tables from the available data. Neither effort is occurring, with the exception of the MITER accounts being developed by the US Department of Agriculture (USDA) and Massachusetts Institute of Technology (MIT) staff, described later on. We note that the construction of tables through survey methods requires at least $200 000 per state. If each of the 51 US regions were to construct such a table, the total would be over $10 million. Thus, the rationale for assembly of a complete set of state tables by a central government unit is obvious.

Elsewhere, developments have been only partially comparable. Dutch regional IO analysis up to the 1970s may be summarized as running 'from regional tables with only limited information used for primarily descriptive purposes towards ideal interregional tables used for analytical purposes, such as estimates of economic impacts, experiments with programming models and building full forecasting models' (Oosterhaven, 1981a, p. 23). As opposed to the Dutch tables constructed in the 1970s and also different from most tables constructed in the United States and in Australia (West, 1990), the Dutch bi-regional tables of the 1980s are mainly based on surveys of export coefficients instead of import coefficients. This change in trade survey strategy also led to the need of an explicit domestic intermediate and final sales table (Boomsma and Oosterhaven, 1992).

This strategy change was the outcome of earlier experiences that showed that firms, as a rule, are better informed about the destination of their output than about the origin of their inputs. This is especially the case if there are many different inputs and/or if inputs are purchased through wholesale or retail channels. Firms are only well informed about the real origin if they deal with one or a few dominant purchases directly from the producer of the inputs. On the sales side, however, firms may lack the necessary information on the spatial destination of their sales only if they primarily sell through wholesale firms. But even then, they appear to be better informed about their sales than about their purchases through wholesale firms.

We will not deal with regional sector-specific models. Although many exist, the issues are similar to those for regional models.[4]

Multi-regional and interregional IO tables and applications

Since the 1960s when Isard (1960) published his text on regional analysis, many IO analysts have considered that interregional input–output (IRIO) or multi-regional input–output (MRIO) tables are needed to derive and compare the direct and indirect economic impacts across regions. As globalization of the markets increases, the need for such tables by analysts increases. In the 1960s, probably as a result of interchanges with the Japanese, who were gathering extensive IO data, Isard set forth an IRIO set of accounts in which each IO coefficient was specified in terms of the region and sector in which the input originated and the region and sector in which it terminated. The Japanese used that interregional accounting framework to construct the first IRIO set of accounts for nine regions and ten commodities for the 1960 and 1963 Japanese economy.

Leontief felt that such detail was not theoretically justified for the technological inputs, because when an engineer makes a widget, the region in which the input was produced should not matter. In his national–regional model, therefore, he did not specify the region of origin of any input (Polenske, 1999). Both Isard and Leontief were correct, in their own way. On the one hand, for determining the technology (production function) of a sector in a particular region an engineer or economist does not need to know the region from which the inputs come. The analyst only needs to know the production technology being used in each region for each sector. Leontief's national–regional and MRIO accounts (Leontief and Strout, 1963; Polenske, 1970, 1980, 1995) therefore require considerably less information, thus cost less and take less time to construct than Isard's IRIO accounts. On the other hand, from a transportation planner's perspective, the regional origin of the input is critical for transportation planning, as well as for tracing the supply chains of commodities (Polenske and Hewings, 2004).

A major innovation with the latest MRIO accounts (Canning and Polenske, forthcoming) is that the data will not only represent actual data from the census, as the first US MRIO accounts did,[5] but the data are being collected from electronic files at the state and county levels, using algorithms that will make it relatively easy to construct accounts in the future, thus greatly reducing the time required to construct these accounts. Special attention is being paid to estimating the suppressed data from the census. Most importantly, the data will be freely available. This is an important consideration given that the data in most other models are available only by paying vendors in conjunction with buying a model.

We note that several US groups, such as IMPLAN (Impact Analysis for PLANning), REDYN (Regional Dynamics), and NIEMO (National Interstate Economic Model) are constructing or have constructed MRIO accounts, but as far as we can determine, they are not making their data freely accessible. IMPLAN has been compared with REMI (Regional Economic Models, Inc.) and with RIMS-II (Regional Input–output Multipliers, version II) by a number of analysts, with the finding that after adjusting for differences in the models, the multipliers are relatively similar. Richman and Schwer (1993, p. 143) for example found 'that apparent changes in the multipliers in each model result from undocumented or poorly documented changes in the vendor default values of the available options for calculating the multipliers, not from structural changes in the models'.

According to the REDYN vendors, their model is 'more flexible and versatile' than other commercially available models, but so far no independent comparative evaluation is available. The REDYN model uses the North American Industrial Classification System at the five-digit detail level (703 sectors), identifies the more than 180 commodities consumed and produced by these sectors, and provides forecasts for over 800 occupations. They obtain the underlying data with the use of County Business Patterns from the US Bureau of the Census, and the Regional Economic Information System from the US Bureau of Economic Analysis. The trade flows are provided for five transportation modes at the county level for 3100 counties. Former REMI staff are constructing REDYN, with the intent to provide on-line capabilities with up-to-date information.

NIEMO is a combined supply–demand-driven IO model developed by analysts at the University of Southern California's National Center for Metropolitan Transportation Research and the Center for Risk and Economic Analysis of Terrorist Events, as part of their research at the Homeland Security Center for Excellence. They constructed the 47-sector model for 52 regions (50 states, Washington, DC, and Rest-of-the-World). The theoretical nature of the iteratively solved model is not entirely clear. One of its main uses so far has been to determine the economic impacts on these regions resulting from a hypothetical terrorist attack on the three major US ports of Long Beach, Newark and Houston (Park et al., 2007) They made use of IMPLAN for the technology part of the model and developed interregional shipments for the 47 sectors, using the doubly constrained Fratar model (Richardson et al., 2005).

The development of several competitive multi-regional IO models is a sign that such analytical impact-assessment tools with real data are in great demand.

Japan is the main country with full interregional IO accounts, which are available for 1960 and every five years since, for 42 prefectures, as well as originally for nine regions, for ten sectors (Abe, 1986). They have set the standard for such detailed assembly of data. Currently, China has MRIO accounts for 1987 constructed over a five-year period in collaboration with the Japanese for seven regions and nine sectors (Ichimura and Wang, 2003; Okamoto and Ihara, 2005). Analysts are using these tables to examine many important regional topics in the rapidly growing economy of China, including factors creating the regional differentials in income. Although the types of studies completed so far are typical economic impact assessments, the availability of improved and detailed current regional data in the near future will provide important possibilities for new analyses on energy, environment, transportation, foreign trade and other current topics.

Since 1995, several countries, such as Canada (Siddiqi and Salem, 1995), the Netherlands (Eding et al., 1999) and Finland (Piispala, 2000), have embarked upon the construction of multi-regional supply and use (commodity-by-industry) tables. Note that not all of these rectangular accounting schemes have a straightforward one-to-one relation with the symmetric IRIO and MRIO models discussed in section 21.2 (Oosterhaven, 1984).

21.5 Modern impact analysis

Today, many analysts are further developing social accounting models (SAMs) and intersectoral computable general equilibrium (CGE) models, and they extensively use such models for economic impact analyses. Regional analysts are conducting numerous economic impact analyses at multi-regional levels in the United States, most of which use one of three computer programs available from commercial vendors: REMI, IMPLAN and RIMS-II, with the matrix multipliers furnished by the US Bureau of Economic Analysis.

REMI is an eclectic multi-regional model that combines economic base, input–output, computable general equilibrium, and econometric methods, and was first put forward for Massachusetts by Treyz et al. (1980). ECOTEC REMI is the daughter model for the United Kingdom, and REMI-NEI is the daughter model for the Netherlands. REMI is a sophisticated regional model with numerous policy variables. Analysts use it to determine environmental pollution impacts, regional impacts of transport infrastructure, including airports, and studies of many large investment projects. Latest versions of REMI include job-accessibility measures and spatial-agglomeration effects.

Mourouzi-Sivitanidou and Polenske (1988) conducted one of the earliest evaluations and comparison of these and other impact-assessment models.[6] One of the most extensive and longest uses of REMI is in Los Angeles by the South Coast Air Quality Management District (SCAQMD), which has used it since 1989 for the determination of job impacts of its rules and regulations, and since 1994 for its tradeable permit Regional Clean Air Management program. The SCAQMD uses it to study job impacts in a four-county (Los Angeles, Orange, Riverside, San Bernardino) region in southern California. Polenske et al. (1992) conducted an extensive 13-month evaluation of the use of REMI by the SCAQMD, determining that as of 1992, the SCAQMD had state-of-the-art impact assessments with the use of REMI. The team provided over 30 recommendations for possible improvements both to the model and to the other evaluation methods being used, many of which have been implemented.

In addition, other readily available regional modeling packages for the United States include IMPLAN and RIMS-II. Each of these packages costs money, with RIMS-II being the least expensive and REMI the most expensive. REMI, however, is the only regional economic model that analysts can use for forecasting over 10–20 years. IMPLAN and RIMS-II have more sectors than REMI, but they can only be used for comparative-static impact assessments.

IMPLAN was started in the 1970s in a combined effort by Lofting at the Berkley Lawrence Livermore National Laboratory and Alward at the US Forestry Service. In 1993, the Minnesota IMPLAN Group was founded by Lindall and Olson, based upon work at the University of Minnesota. At the forest service starting in the 1970s, Alward and others developed Micro-IMPLAN, an input–output impact model specifically designed to meet the US Department of Agriculture (USDA) Forest Service needs. Results for four years (1990, 1985, 1982 and 1977) are reported by Shields et al. (1995).[7] The major characteristics of IMPLAN Version I, which is no longer used, were: (1) industry-by-industry accounting; and (2) supply–demand pooling technique for trade estimations. IMPLAN Version II is the basis for all subsequent IMPLAN software, including the current (2006) release of MicroIMPLAN Rel 91–F. Its principal characteristics are: (1) rectangular accounting (that is, make-and-use matrices); and (2) regional purchase coefficients (RPCs) for trade estimation.

IMPLAN differs from REMI in several ways. First and perhaps most importantly, IMPLAN is a static IO impact model, based on the latest national IO table (as of 2008 for the year 2002). In contrast, REMI is a dynamic input–output, econometric forecasting and simulation model, in which Bureau of Labor Statistics forecasts of the input coefficients are used to obtain regional technology forecasts for up to 20 years. The 2008 version of IMPLAN contains 400+ sectors, while REMI has only 57. Second, IMPLAN initially used the 1963 regional IO data assembled in a manner similar to the national IO data for the 50 states and Washington, DC, by Polenske (1980). When these regional technologies became more and more dated, they switched to using location quotients (LQs) to adjust the national IO coefficients, and currently they are using regional purchase coefficients (RPCs) estimated from trade flows. Starting from the initial REMI model, Treyz recognized the superiority of using RPCs over LQs.

Although adjustments using RPCs create more accurate estimates than LQs and are relatively inexpensive, some analysts, including the current authors, believe that the best method is to assemble US regional IO tables using the same data sources the Bureau of Economic Analysis uses for the national data. That is the thrust of the MITERS research, in which staff from the Massachusetts Institute of Technology and the Economic Research Service of the US Department of Agriculture are constructing multi-regional accounts at a county level and for approximately 200 sectors. They use GAMS (General Algebraic Modeling System) to create input files from census and other data to help estimate suppressed data.

Several analysts are designing new multi-regional program packages in attempts to make the models suitable for use in modern impact assessments, such as for distribution of agricultural goods, terrorist attacks, air transportation impact, and so on. Examples include Lahr who redesigned Stevens's PC-IO package, and the University of Southern California (USC) staff who designed the NIEMO model discussed above. These multi-regional models are used by numerous state and county groups, and academics.

An important extension of the direct, indirect and induced impact analysis is determination of so-called catalytic effects. For air transportation, Oxford Economic Forecasting distinguishes between supply-side and demand-side catalytic effects, with the supply-side effects indicating the performance of the economy and long-run productivity and livability, and the demand-side effects including the use of air services to transport goods, business travelers and tourists (Cooper and Smith, 2005, p. 16).

In Europe, the need to evaluate a series of large transport infrastructure projects led to IO-type new economic geography (NEG) models (Venables, 1996). Because freight and passenger transport cost reductions impact upon different sectors differently, analysts use an interregional inter-industry approach. Different regions sell varieties of the output of each sector on monopolistically competitive regional markets, linked by transport cost. Sectoral CES-aggregates of these varieties are combined in Cobb–Douglas consumption and production functions (in the latter case also with capital and labor). In these inter-industry NEG models, transport cost reductions increase each region's exports (demand) as well as imports (supply). The net economic impact may well be negative for some sectors in some regions, while causing clustering of sectors and agglomeration of economic activity in other regions (see Venables and Gasiorek, 1996; Oosterhaven and Knaap, 2003; Thissen, 2005, for seminal applications).

21.6 Conclusion

Regional analysts are incorporating new theoretical perspectives related to economic geography into their socio-economic impact models. We have reviewed the basic Types I, II and III input–output quantity and price models and summarized the state of the art in regional and interregional impact analysis. From this, we conclude that the future will continue to feature interregional inter-industry models, as the sector-specific and location-specific nature of the employment, energy and emissions impacts of all kinds of exogenous shocks and policy measures requires such modeling. Increasingly, however, these models will feature non-linear production and consumption functions, and integrate simultaneous price and quantity impacts in models with non-perfect competition.

Obviously, the collection and processing of regional technology and regional trade data remain a time-consuming and expensive task. Given the need for regional and interregional impact analyses, in the United States several different groups are constructing multi-regional models. Because most of this work is unpublished at the present time (2008), we have presented information gleaned from websites, personal conversations and personal involvement. From this overview, we conclude that new spatial theories are needed before analysts can make significant advances on applications and that there is no real substitute to survey-based, inter-industry, interregional information and modeling.

Notes

1. The InterRegional Input–Output Software package IRIOS (Stelder et al., 2000), which is based on a flexible generalization of impact equation (21.6), is freely downloadable at www.REGroningen.nl/irios.
2. Note that de Mesnard (2006) takes offense at the use of the word 'multiplier' in this case and proposes an alternative net multiplier definition. See Oosterhaven (2007) for a reply and Dietzenbacher (2005) for an independent evaluation.
3. The first Washington State table was assembled in 1967 by Tiebout, Bourque, Thomas, and other faculty at the University of Washington, and faculty at Washington State University in Pullman, who assembled the agricultural components. Washington State tables are available from surveys conducted for 1963, 1972, 1982, 1987, 1997, and 2002 (as of 2008, the 2002 one is just being completed). Two 1997 tables were constructed, one with industrial sectors defined by the Standard Industrial Classification (SIC), the other by the North American Industrial Classification System (NAICS), with employment, income and output multipliers for each classification scheme for 38 and 62 sectors (Illman, 1996; State of Washington, 2004).
4. One example is the Port Economic Impact Kit (Klaers, Powers & Associates, 2001). It has a customized national IO model for the port's region. The direct economic impacts include those generated by the transhipment of cargo as well as capital investments made by waterfront facilities. The indirect and induced impacts are obtained from the purchases required by this direct expenditure and by the wages paid to the labourers in direct and indirect activities. Estimates are also made of the property taxes and occupation taxes paid by the various facilities.
5. The United States has 1963, 1972 and 1977 MRIO accounts for 51 regions (50 states and Washington, DC) and 79 to 120 sectors (Polenske, 1980), and will have by early 2009 1997 and 2002 MRIO accounts for 3076 counties plus about 500 ports of entry and 162 sectors; all the latter data for all years are constructed from census and other official US data, mostly using electronic files (Canning and Wang, 2005; Canning et al., 2007).
6. The website: http://www.remi.com/support/articlescomplete.shtmllist) lists an additional 23 evaluations.
7. See for details on the early IMPLAN research: http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr 95.pdf.

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