IMPACT OF DEMOGRAPHIC CHANGE ON INDUSTRY STRUCTURE IN AUSTRALIA

A joint study by the Australian Bureau of Statistics, the Department of Employment and Industrial Relations, the Department of Environment, Housing and Community Development, the Department of Industry and Commerce and the Industries Assistance Commission

CONFIDENTIAL : Not for quotation without prior clearance from the authors; comments welcome

ADVANCES IN INPUT-OUTPUT ANALYSIS : A REVIEW ARTICLE

by

Peter B. Dixon

and

B. R. Parmenter

La Trobe University and Industries Assistance Commission

Preliminary Working Paper No. IP-06 Melbourne October 1978

The views expressed in this paper do not necessarily reflect the opinions of the participating agencies, nor of the Australian government.

IMPACT Project, Industries Assistance Commission, 608 St. Kilda Road, Melbourne, Victoria 3004 Australia
Area Code 03 Telephone 51 8611

[28] Polenske, K.R., "Multiregional interactions between energy and transportation". P-S volume, chapter 21.

[29] Polenske, K.R. and J. Skolka (eds.), Advances in Input-Output Analysis, (Proceedings of the Sixth International Conference on Input-Output Techniques, Vienna, April 1974). Ballinger Publishing Company, Cambridge, Mass. 1976.

[30] Petri, P.A., "A multilateral model of Japanese-American trade". P-S volume, chapter 23.

[31] Schultz, S., "Intersectoral comparisons as an approach to the identification of key sectors". P-S volume, chapter 7.

[32] Sevaldson, P., "Price changes as causes of variations in input-output coefficients". P-S volume, chapter 6.

[33] Shishido, S. and A. Oshizaka, "Inventory adjustment in a quarterly input-output model for Japan". P-S volume, chapter 3.

[34] Taylor, L. and S.L. Black, "Practical general equilibrium estimation of resource pulls under trade liberalization," Journal of International Economics, 4 no. 1, February 1974.

[35] Thoss, R., "A generalized input-output model for residuals management". P-S volume, chapter 20.

[36] Tokoyama, K., Y. Kobayashi, Y. Murakami and J. Tsukui, "Structures of trade, production and development". P-S volume, chapter 22.

[37] Vanwynsberghe, D., "An operational non-survey technique for estimating a coherent set of interregional input-output tables". P-S volume, chapter 14.

[38] Volkonskii, V., "The role of intersectoral models in determining the discount rate". P-S volume, chapter 28.

[39] Weisskoff, R., "Income distribution and export promotion in Puerto Rico". P-S volume, chapter 10.

[40] Wigley, K.J., "Production models and time trends of input-output coefficients". In Input-Output in the United Kingdom, W.F. Gossling (ed.), London, Frank Cass and Co. Ltd., 1970.

Advances in Input-Output Analysis

A Review Article

by

Peter B. Dixon

and

B.R. Parmenter

La Trobe University and Industries Assistance Commission

Abstract

This paper reviews the volume, Advances in Input-Output Analysis, edited by Polenske and Skolka and published by Ballinger. The volume contains proceedings of the most recent international conference on input-output techniques. Contributions to the volume are appraised in assessing extension of the input-output approach into the areas of short-run forecasting, regional analysis, environmental problems, income distribution and dynamic analysis. The integration of the input-output model into more sophisticated economic models is then considered. The required improvements in the specification of the trade sector, the demand side, supply constraints and technology are discussed.

[14] Hoffman, R.B. and J.N. Kent, "Design for commodity-by-industry interregional input-output models". P-S volume, chapter 12.

[15] Ivanov, I.N., "A dynamic optimal plan of economic growth". P-S volume, chapter 27.

[16] Johansen, L., A multi-sectoral study of economic growth, North Holland Publishing Co., 1972.

[17] Kendrick, D., "On the Leontief dynamic inverse". Quarterly Journal of Economics, 86, no. 4, November 1972.

[18] Kuyvenhoven, A., "Sector appraisal where trade opportunities are limited". P-S volume, chapter 9.

[19] Leontief, W., The Structure of the American Economy 1919-1929. New York:OUP, 1941.

[20] Leontief, W., "Environmental repercussions and the economic structure : an input-output approach". Review of Economics and Statistics, 52, no. 3, August 1970.

[21] Leontief, W. and D. Ford, "Air pollution and the economic structure : empirical results of input-output computations". In Input-Output Techniques, A. Brody and A. Carter (eds.), North Holland Publishing Co., 1972.

[22] Leontief, W., A. Morgan, K. Polenske, D. Simpson and E. Tower, "The economic impact - industrial and regional - of an arms cut". Review of Economics and Statistics, 47, no. 3, August 1965.

[23] Leontief, W. and A.Strout, "Multiregional input-output analysis". In Structural Interdependence and Economic Development, T. Barna (ed.), MacMillan, 1963.

[24] Livesey, D.A., "A minimal realization of the Leontief dynamic input-output model". P-S volume, chapter 25.

[25] Ozaki, I., "The effects of technological changes on the economic growth of Japan, 1955-1970". P-S volume, chapter 5.

[26] Panchamukhi, V.R., "A multisectoral and multicountry model for planning ECAFE production and trade". P-S volume, chapter 24.

[27] Paukert, F., J. Skolka and J. Maton, "Redistribution of income, patterns of consumption and employment : a case study for the Philippines". P-S volume, chapter 8.

REFERENCES

[1] Artus, J.R. and R.R. Rhomberg, "A multilateral exchange rate model". IMF Staff Papers, Vol. XX, November 1973.

[2] Barker, T.S., "Projecting alternative structures of the British economy". P-S volume, chapter 1.

[3] Bodkin, R.G., "A large-scale input-output econometric model of the Canadian economy (CANDIDE)". P-S volume, chapter 2.

[4] Buckler, M.C., D. Gilmartin and T.C. Reimbold, "The INFORUM model". P-S volume, chapter 15.

[5] Carter, A.P., "Changes in the structure of the American economy, 1947 to 1958 and 1962". Review of Economics and Statistics, 49, no. 2, May 1967.

[6] Chenery, H.B., "Interregional and international input-output analysis". In Structural Interdependence of the Economy, T. Barna (ed.), New York, John Wiley and Sons, 1956.

[7] Courbis, R. and D. Vallet, "An interindustry interregional table of the French economy". P-S volume, chapter 11.

[8] Cumberland, J.H. and B.N. Stram, "Empirical application of input-output models to environmental problems". P-S volume, chapter 18.

[9] Den Hartog, H. and A. Houweling, "Pollution, pollution abatement, and the economic structure of the Netherlands". P-S volume, chapter 19.

[10] Dixon, O., P. Dixon and J. Miranowski,"Insecticide requirements in an efficient agricultural sector". Review of Economics and Statistics 55, no. 4, November 1973.

[11] Duval, A., G. McNeill and N. Jeantet,"Use of the Wigley production function in a static general equilibrium model applied to France". P-S volume, chapter 26.

[12] Emerson, M.J., "Interregional trade effects in static and dynamic input-output models". P-S volume, chapter 13.

[13] Haig, B.D. and M.P. Wood, "A dynamic model for analysing price changes". P-S volume, chapter 4.

Contents

Petri's [30] for example, bear the mark of simplifications which may have been introduced for computing reasons. Johansen [16] suggested an alternative method of obtaining approximate solutions to non-linear general equilibrium models. His method, grand in the spirit of the original Leontief simplification, involves linearizing the model by logarithmic differentiation and obtaining an "elasticities" solution to the linearized model by matrix inversion. Applications of this fruitful method are, unfortunately, not represented in the P-S volume.

The papers reproduced in the P-S volume demonstrate two fundamental types of flexibility in the input-output structure. Firstly, they prove that the method can provide illuminating analysis of a very wide range of policy issues. Secondly, they show that the basic insights of the input-output model can usefully be employed in much more elaborate applied economic models with considerably extended theoretical structures. It is because of these flexibilities that international input-output conferences continue to provide new evidence of the value of Leontief's contribution as a basis for applied economic research.

An alternative approach is that suggested by Wigley [40] and described in the P-S volume by Duval, McNeill and Jeantet [11]. Wigley's method, which is employed by the Cambridge Growth project, attempts to model embodied technological change of the type assumed in vintage production functions.

4. CONCLUSION

This review has concentrated on the input-output method as a tool for applied economic analysis. The stark assumptions of the input-output approach are unnecessarily restrictive from the point of view of pure theory. The importance of input-output economics is that it provides a vehicle for the empirical implementation of much of general equilibrium theory.

A necessary feature for empirical models is that their solutions be computable. Computing limitations are proving to be increasingly transitory in the face of technological change. As the editors of the P-S volume point out in their introduction, for linear models problems of obtaining a solution are no longer serious. For large models with fine sectoral disaggregation, especially when new dimensions, regional or environmental for example, are added, problems of data storage and handling may arise. Hoffman and Kent [14] discuss aspects of these issues. Many of the developments discussed above, especially in section 3, involve non-linear elements in the structural forms of input-output based models : neo-classical production functions for example. Non-linear solution algorithms for general equilibrium models are of course available but may impose limits on the size and scope of the model unacceptable from the point of view of policy analysis. Some of the contributions to the P-S volume,

Advances in Input-Output Analysis : A Review Article

by

Peter B. Dixon
and
B. R. Parmenter

La Trobe University and Industries Assistance Commission

1. INTRODUCTION

The appearance of a volume of proceedings of the Sixth International Conference on Input-Output Techniques [29] held in Vienna in 1974 provides an opportunity for the reappraisal of the usefulness of input-output models. The twenty-nine papers reproduced in the volume (hereafter referred to as P-S) present input-output techniques applied to a wide range of problems. Some studies use input-output analysis alone; others embed an input-output module in a more elaborate economic model.

Consider Leontief's original formulation of the basic, open, static input-output model [19] ,

$$X = AX + Y . \qquad (1.1)$$

A vector of gross outputs (X) by n industrial sectors is determined as a function of a vector of final demands (Y) taking account of the interdependence between sectors through intermediate inputs. The ij^{th} element of the matrix A shows the input from sector i required per unit output of sector j . In the basic model A is a parameter and Y is exogenous.

The associated price model is

$$p' = p'A + v'L \quad , \qquad (1.2)$$

where p is a vector of unit prices of the sector outputs, v is a vector of value added prices and L is a matrix the ij^{th} element of which is the input of primary factor i required per unit output in sector j . L is a parameter and v is taken as exogenous. Without changing the basic theoretical structure, the system (1.1) and (1.2) can be generalized to break the implied nexus between commodities and industry outputs and to accommodate a rectangular technology matrix, cf. Bodkin [3].

The evidence of the P-S volume is that the theoretical structure of Leontief's basic system, although now more than forty years old, is still widely applied in empirical analysis. Some papers in the volume use models like (1.1) almost unadorned. Weisskoff [39] for example uses such a model to given an historical dissection of Puerto Rican growth performance. Many others retain the formal structure of the basic model but extend the scope of its application. The ease with which the scope of the basic Leontief approach can be so extended no doubt accounts in part for its continuing popularity.

In section 2 of this review article an assessment is made of extensions reported in the P-S volume of the input-output methodology into five areas : short-term forecasting, regional analysis, environmental issues, income distribution and dynamic analysis. Extensions of this kind are motivated by the desire to use the input-output method as an aid in the analysis of problems not addressed by the simple system outlined above.

In section 3 of the review, extensions to the theoretical structure itself are considered. In contrast to section 2, these extensions are

of the latter type. Costs are clearly involved in abandoning the fixed coefficient simplification and the question arises as to whether input substitution could profitably be introduced into input-output models more generally.

Sevaldson [32] provides some evidence relevant to this last question. Using a long time series of Norwegian input-output tables, he rejects the idea that changes in technology coefficients are closely related to changes in relative prices as would be implied by a cost minimizing assumption for producers. His results imply that attempts to model materials/materials substitution in response to changes in relative prices are likely to be unfruitful.

This is not to say that technological coefficients ought to be assumed constant over time. The P-S volume also contains evidence relevant to this question. Both Weisskoff [39] and Buckler, Gilmartin and Reimbold [4] investigate the sensitivity of results from input-output models to changes in the technology matrix. The latter find that coefficient adjustments are important, relative to improvements in final demand projections, in reducing errors in simulations with the INFORUM model. It should be noted however that, for the period tested, their final demand projections are quite accurate. Ozaki [25] investigates the extent of coefficient change in some Japanese input-output data. His results generally confirm the earlier conclusions of Carter [5] for the U.S. that changes in primary input coefficients are more important than changes in materials coefficients and that labour coefficients exhibit fairly well defined downward trends for most sectors. This last result is also confirmed by Sevaldson. The conclusion seems to be that changes in technology coefficients should not be ignored but that they might be handled by the imposition of exogenous technology scenarios rather than endogenous modeling of coefficient changes.

produced in Barker's model by an increase in government spending. Government services are typically of above average labour intensity. A similar result is evident in the pollution model presented by Thoss [35]. Again labour is the only factor assumed to be scarce and the solution of the model subject to full employment and pollution constraints generates a large increase in the generation of electricity from hydro-electric sources. It is unlikely that this result would be robust under the imposition of relevant capital and natural resource constraints.

Contributions to the P-S volume demonstrate clearly the importance of specifying acceptable supply constraints for input-output models and in particular the need to avoid specifications which lead to spurious results from implausible changes in factor proportions. Important elements of costs, such as capital, should not be implicitly assumed zero. A specification involving aggregate labour and capital constraints, neo-classical production functions and exogenous relativities between sectoral rates of return would seem to be a sensible combination for long-run simulations.

3.4 The technological specification

The fixed coefficient technology assumption is the most obvious simplification introduced by the input-output representation of the economy. This assumption rules out all substitution in industries' input structures in response to changes in relative input prices. In input-output based general equilibrium models it is now quite common for this assumption to be relaxed with respect to primary input substitution (cf. [34]) and substitution between alternative sources, (i.e., foreign versus domestic) of inputs of the same commodity classification (cf. [1]). The models described by Barker [2] and by Petri [30] both implicitly incorporate input substitution

attempts to overcome perceived shortcomings in results generated from simple input-output models under the standard interpretation. The exogeneity of final demand and the stark technological assumptions of the basic model are obvious weaknesses. More important is the lack of an explicit supply side. Primary factor constraints are entirely absent from models like (1.1). Similarly the exogeneity of primary factor prices in (1.2) implies perfectly elastic supplies of primary factors. The importance of appending a fully specified supply side to input-output models is emphasized in section 3.

2. EXTENDING THE SCOPE OF THE BASIC LEONTIEF MODEL

2.1 Short-term forecasting

The standard interpretation of an open static input-output system such as (1.1) and (1.2) is that it provides medium or long-term projections. The system amounts to a single period model in which changes in demand are fully accommodated by changes in output and in which prices respond completely to changes in costs. Essentially the same interpretation is adopted in many of the more elaborate, input-output based models. In the P-S volume, the model described by Barker [2] is an example.

In its basic form the input-output system is not suitable for short-run (say, quarterly) forecasting of output and price responses. For that purpose explicit modeling of inventories as a buffer between demand and output and of the lags in the response of price changes to cost changes is essential. Purely statistical studies of these short-run timing phenomena are common, especially in the literature surrounding disequilibrium macroeconomic models. Forecasting models based on this type of analysis can often be shown to track in their sample periods quite closely or to forecast satisfactorily in a period which exhibits the same sort of movements in economic magnitudes as were experienced in the sample period. Under such circumstances, however, the forecasting task is not especially hard : various kinds of extrapolatory methods can give quite accurate forecasting results. The major shortcoming of the ad hoc statistical approach to forecasting is that it provides little basis for predicting the effects of sudden large changes in economic phenomena : a sudden doubling of energy prices (say) as opposed to the continuation of a gradual upward drift.

The P-S volume contains two papers which demonstrate how input-output methods can add more theoretical structure to short-run forecasting models. Haig and Wood [13] explain quarterly movements in the Australian consumer price index using an estimated index explicitly built up from price movements at the sectoral level. Input-output data on sectoral cost structures are combined with a fixed mark-up pricing rule. Lags in the passing on of materials and labour costs are related to average turnover times for inventories of materials and finished goods or work in progress respectively. Shishido and Oshizaka [33] incorporate an input-output structure in tracing the quarterly effects of changes in final demands on sectoral levels of output and inventory accummulation. Unlike Haig and Wood, however, they resort to purely statistical techniques to establish the lag structures.

In addition to accounting explicitly for intermediate flows, the use of an input-output approach in short-run forecasting models also allows different behavioural assumptions for different sectors. Haig and Wood [13] for example, recognize that the mark-up pricing model is not appropriate

becomes just a demand side variable in the snapshot year, although it should presumably bear some sensible relationship to capital accumulation over the solution period.

Pitfalls to be avoided in the specification of a supply side for long-run, input-output models will be uncovered by a comparison of the approaches taken by Barker [2] and Petri [30]. In particular, the effects of devaluation in their models are considered. Petri, whilst recognizing the possibility of more sophisticated alternatives, implements a multi-country model with a single, inter-sectorally mobile primary factor in each country. The money wage in each country is exogenous. Under full employment assumptions devaluation increases a country's exports and reduces its imports via trade flow equations of the form of (3.1.4) and (3.1.5) described in section (3.1) above. The exogeneity of the money wage allows the devaluation to produce the permanent increase in the relative prices of traded goods necessary for it to have real effects in the long run. Domestic absorption must fall in order to release resources to accommodate the increased net trade surplus. GDP is fixed by the primary factor endowment.

The single country model described by Barker again has only a single primary factor constraint, labour, and an exogenous money wage. The model is however implicitly a two factor model with a fixed mark-up pricing rule, no capital constraint and sectors of varying labour itensities. Under these assumptions the long-run effects of devaluation include an increase in GDP generated by a shift of scarce labour into capital intensive export industries and a consequent rise in the average capital intensity of the economy. The size of the capital stock is completely demand determined. Note that this interpretation also explains the reduction in GDP is to be used to produce plausible projections, relevant supply side constraints must be appended. Weisskoff [39] in his model of the Puerto Rican economy, for example, explicitly assumes that labour is in excess supply and imposes neither an aggregate capital constraint nor a balance of payments constraint. The sectors of the economy are, therefore, in no way competitive on the supply side and any increase in demand, a program of import replacement for example, will increase aggregate employment. The implausible implication is that, even in the long run, employment creation is just a matter of demand stimulation. In a similarly unconstrained model of the Philippines, Paukert, Skolka and Maton [27] derive an essentially Keynesian increase in GDP and employment from an egalitarian redistribution of income which reduces the average savings ratio. Such an implicitly short-run analysis of a long-run phenomenon - a change in income distribution - does not seem of great interest. Its shortcomings are revealed by complementary results presented in the same paper which indicate that, by reducing the investible surplus, the redistribution lowers the available rate of growth. Other problems of interpreting input-output models with no supply constraints have already been referred to in the context of key sector appraisal [31], [18], and regional modeling [7], [14], [37], [28].

For long-run models supply constraints are generally essential. Employment constraints, in the absence of well defined theories of labour supply, are generally regarded as exogenous. Capital constraints may be endogenous in models which explicitly accumulate through time. Investment is then both a demand and a supply side variable. Ivanov [15] for example incorporates such a structure. In single period, "snapshot" long-run models the capital constraint is best imposed exogenously. Investment

for all sectors and for this reason they treat some prices as exogenous. For both these reasons a sectoral approach using an input-output framework may be the appropriate level at which to pursue attempts to impose better theoretical structures on short-term forecasting exercises even where the overall concern is with macro aggregates.

2.2 Regional analysis

The input-output method has proved to be particularly attractive to economists interested in regional analysis. In this context the method has been applied in two distinct ways : as a framework for the formulation of single region models and in an extended form which accommodates a multi-regional dimension in a single model. Apart from the problems of assembling inter-sectoral flow data at the regional level, the basic weakness of the single region approach is that inter-regional trade cannot adequately be explained on the basis of developments in a single region. The regional economy is typically much more open than the national economy. Since the trade sector is therefore so much more dominant in determining the level and structure of economic activity within the region, the modeling of inter-regional trade flows is crucial. Simultaneous treatment of demand and/or supply factors in mutually trading regions, that is a multi-regional approach, would seem to be required. Emerson [12] presents some results of a single region model of Kansas which concentrate on the stability of import coefficients. No detailed framework for explaining changes in the coefficients is possible at the single region level and it is difficult to extrapolate the results beyond their immediate context.

Four examples of multi-regional input-output models are offered in the P-S volume : [7], [14], [37] and [28]. These models conform strictly to the theoretical structure of the basic Leontief system described by equation (1.1). That is, they can be written as :

$$X^R = ZX^R + Y^R \quad , \qquad (2.2.1)$$

where X^R is a vector of gross outputs by sector and region (i.e., for a model with n sectors and m regions, X^R consists of m $(n \times 1)$ vectors of regional sectoral outputs). Y^R is an $(mn \times 1)$ vector of final demands for regional sectoral outputs and Z is an $(mn \times mn)$ matrix from which the typical element, $Z_{(ir)(js)}$, shows the input from sector i in region r required per unit output of sector j in region s. Notice that in (2.2.1) Y^R is not a natural exogenous variable. It is usual to regard the $(mn \times 1)$ vector of final demands originating in each region $(\tilde{Y})$ as exogenous and to generate Y^R endogenously via some sourcing assumptions.

Differences between various versions of the basic multi-regional model (2.2.1) can be explained in terms of alternative ways in which Y^R and Z are generated. Hoffman and Kent [14] discuss this at the most general level. They envisage regionalizing a rectangular national model selectively in either its industry or its commodity dimensions, or both, according to analytical purpose and data availability. Regional commodities and industries are treated just as more finely disaggregated commodities and industries. Their approach is appealingly pragmatic and it would be interesting to see how the generation of Z and Y^R proceeds in examples of specific implementation of this Canadian model.

The Rococo method, described by Vanwynsberghe [37] in the context of a multi-regional model of Belgium, follows basically the procedures suggested by, for example, Chenery [6]. The matrix Z and the vector Y^R are defined as follows :

The key sector method can best be understood as a poor man's approximation to an explicit programming approach to the selection of a development strategy. Its problems would be avoided by an explicit programming model which maximizes some objective function, the value of GDP at world prices for example, subject to an appropriate set of demand and supply constraints. The programming interpretation also focuses attention on the plausibility of the objective criterion. The validity of the criteria implied by some of the frequently used key sector indicators is far from obvious. This is especially true of the gross output measures. Schultz [31] suggests that these might be highly correlated with more conventional indicators of economic development, GDP per head for example. This empirical observation would not appear sufficient ground for replacing the latter by the former in sector selection criteria.

Kuyvenhoven [18] presents a sophisticated version of the key sector method which avoids some of the difficulties associated with cruder applications. Demand side problems are mitigated by concentrating on trading sectors which are assumed to trade on perfectly competitive world markets and in the absence of domestic trade restrictions. Capital is explicitly assumed to be the only scarce factor. Consistent with this assumption, the criterion chosen is GDP generated, both directly and in indirectly stimulated non-trading sectors, per unit investment directly and indirectly required. No balance of payments constraint is imposed however, a problem which is easily avoided in an explicit programming formulation.

3.3 The supply-side specification

Projections from open static input-output models are basically demand determined. For many applications, if the input-output framework models proposed by Barker and Petri hinder the application of this more satisfactory approach. The question of the appropriate supply side specification is considered in section 3.3 below.

3.2 The final demand specification and "key sector" identification

The basic input-output model, equation (1.1), takes final demand as exogenous and is able to trace the implications for gross outputs of any projected level and composition of demand. The model itself says nothing about what is the appropriate vector of final demands. The key sector approach attempts to use the simple input-output model to identify which sectors in an economy ought to be stimulated. An arbitrary increase in final demand is hypothetically imposed on each sector in turn and the effects on various economic magnitudes are computed. The magnitudes typically chosen are aggregate gross output (via indicators of backward or forward linkages), aggregate employment, net foreign exchange earnings and aggregate GDP. Schultz [31], for example, produces measures for all of these. Such measures may account for direct effects only or, more usually, for direct and indirect effects via the use of the Leontief inverse.

The problem, arising from the exogenous treatment of final demand, is that, although key sector identification is an attempt to decide how the sectoral pattern of final demand should be directed, nothing is said about the relative values to final users of the alternative demand patterns. In addition the usefulness of the key sector approach in conjunction with a simple input-output model is limited by the weakness of the supply side of the input-output model. It fails to account for the possibility that sectors are constrained on the supply side via their competing demands for scarce factors : land, labour, foreign exchange and especially capital.

$$Z = CA^R \qquad (2.2.2)$$

$$Y^R = C\tilde{Y} \quad . \qquad (2.2.3)$$

A^R is a block diagonal matrix where the blocks are m $(n \times n)$ matrices of technology coefficients. The ij^{th} element of the s^{th} such matrix is $a_{(i.)(js)}$: the total input from sector i required per unit output of sector j in region s. In multi-regional studies these coefficients are often assumed equal to national input-output coefficents, (i.e., it is often assumed that $a_{(i.)(js)} = a_{ij}$ for all s). This assumption however is in no way essential for models of the form of (2.2.1) and may give misleading results. Polenske [28] for example emphasizes the importance of allowing for regional variation in the technology of electricity generation in a multi-regional model of the U.S..

C is a matrix of coefficients which define how regional users of the output of each sector source their supplies among producing regions. The assumption is that all users of commodity i in region r draw their supplies from producing regions in the same proportions. This assumption removes the need for a sector of use dimension in the required inter-regional flow data. C consists of m columns of m $(n \times n)$ diagonal matrices. The i^{th} diagonal element of the r^{th} such matrix in the s^{th} of the columns is given as :

$$C_{(ir)(is)} = x_{(ir)(.s)} / \sum_r x_{(ir)(.s)} \quad , \qquad (2.2.4)$$

where $x_{(ir)(.s)}$ is the total usage in region s of the output of sector i in region r .

In the absence of inter-regional flow data, various general methods can be employed for generating the matrix C. For example, in 1965 Leontief, Morgan, Polenske, Simpson and Tower [22] (hereafter LMPST) suggested a method of cutting through the data problems by recognizing a simple dichotomy between regionally traded (national) and regionally non-traded (local) commodities. Although such a dichotomy is in the end arbitrary, for many sectors, especially the trade and service sectors, local sourcing is technologically implied. Where regions are defined so that only a small percentage of consumers are located near the borders, local commodities, with minimal inter-regional trade, are easy to identify. The state level of disaggregation of the Australian economy is an excellent example. Where population is more evenly spread the LMPST dichotomy will be less useful.

The LMPST method does not specifically model regional users' sourcing of national commodities. However, if it is assumed that regional output shares of national sectors are fixed, the LMPST method is consistent with the imposition, for those sectors, of the assumption that the proportions in which users draw their supplies from producing regions is independent of the users' regional locations. That is :

$$C_{(ir)(is)} = x_{ir} / \sum_r x_{ir} \quad \text{when } i \text{ is a national industry.} \qquad (2.2.5)$$

Intra-regional sourcing is, of course, assumed for usage of the output of local sectors. Under this interpretation the LMPST model can be represented within the framework of equations (2.2.1) - (2.2.3). For a two region case in which, within each region, sectors are arranged into groups first of local sectors (L) and second of national sectors (N), the appropriate matrix C is

A more satisfactory approach is to extend the theoretical framework of the input-output model to allow imports to be imperfect substitutes for domestic output. Barker [2] and Petri [30] employ this specification in input-output based models. Both model import flows directly via econometrically estimated equations of the form :

$$M^i = f\left(D^i_d , P^i_f / P^i_d\right) , \qquad (3.1.4)$$

where M^i is imports of commodity i, D^i_d is a measure of the aggregate domestic demand for i, P^i_f is the import price and P^i_d the price of the equivalent domestic product.

In the single country model of the United Kingdom described by Barker, exports also are determined by estimated equations of a form analogous to (3.1.4). Petri's is a multi-country model and uses equations like (3.1.4) to determine import flows (M^i_{rs}) between specific pairs of countries r and s. Exports are then determined by the identity

$$M^i_{rs} \equiv E^i_{sr} , \qquad (3.1.5)$$

where E^i_{sr} is the export of i from s to r.

Note that both Barker and Petri introduce an unfortunate inconsistency into their models by employing commodity balance equations of the form of (3.1.3) despite their assumption that imports and domestic supplies are not perfect substitutes. This last type of confusion is avoided in models which do not specify trade flows directly. For example, Artus and Rhomberg [1] employ standard theories of demand and production to generate, explicitly for each country, the demand for and supply of commodities distinguished by country of origin and sector. Import and export flows are then naturally implied. Weaknesses especially on the supply sides of the of exports (E) is almost always taken as exogenous. Within the input-output framework there are two common alternatives for the modeling of imports. Firstly, imports might be regarded as non-competitive. Even if the import vector (M) is designated in the same commodity classification as domestic output (X), substitution between imports and domestically produced commodities is ruled out. Such a model might be written as

$$X = A_d X + Y_d \qquad (3.1.1)$$

$$M = A_m X + Y_m \ , \qquad (3.1.2)$$

where Y_d and Y_m are, respectively, vectors of exogenous final demands for domestic output and imports. The matrices A_d and A_m are, similarly, matrices of input-output coefficients distinguishing between domestic and imported inputs. This is the approach adopted by Paukert, Skolka and Maton [27].

Alternatively, domestic output and imports of the same commodity classification might be treated implicitly as perfect substitutes and summed in a single commodity balance equation as follows :

$$X = AX + Y - M \ , \qquad (3.1.3)$$

where Y is now interpreted as a vector of final demand for commodities and A is a technology matrix. Under this specification the determination of the shares of imports in domestic usage is a problem. When (3.1.3) is incorporated in a linear programming model or a model in which users are assumed to minimize costs the "flip-flop" problem arises with import shares alternating between zero and one according to relative prices. This problem is encountered by Tokoyama, Kobayashi, Murakami and Tsukui [36].

		REGIONS 1 Sectors L	REGIONS 1 Sectors N	REGIONS 2 Sectors L	REGIONS 2 Sectors N
Region 1	L	I	0	0	0
	N	0	$\hat{C}_1$	0	$\hat{C}_1$
Region 2	L	0	0	I	0
	N	0	$\hat{C}_2$	0	$\hat{C}_2$

where the $\hat{C}_r$ matrices are diagonal and impose the assumption (2.2.5) for the usage of national commodities.

A less restrictive, but more data demanding, general method for generating the $x_{(ir)(.s)}$ is the gravity model of Leontief and Strout [23]. Inter-regional flows of commodities are assumed to depend on the sizes of using and producing regions and on the distances between them. Rather than resorting to such general methods, Vanwynsberghe [37] and Polenske [28] use primary data on inter-regional trade flows.

In all of these multi-regional input-output models the size and location of sector outputs is demand determined. That is, the regional outputs of sectors are determined by Y^R. The sourcing assumptions built into the matrix C are therefore of overriding importance in determining the regional outcome of exogenous changes in $\tilde{Y}$. Courbis and Vallet [7] suggest that the REGINA model of the French economy includes region specific supply constraints as well as the usual demand side. Unfortunately, no results from this model are presented in the P-S volume. For very long-run analysis, however, regional differentiation among supply variables might be of little importance if high levels of inter-regional factor mobility are assumed.

Before leaving the topic of regional input-output analysis it is interesting to note the formal similarity of the multi-regional models and some multi-national models. Panchamukhi [26] suggests such a model for five countries of the ECAFE region. The structure of the model is exactly similar to (2.2.1) and (2.2.2). The vector Y^R is taken as exogenous. Trade flows however are assumed to be proportional to sectoral outputs in the countries rather than, more naturally, to sectoral demands. The implied matrix Z has, for a two country case, the form :

$$Z = \begin{bmatrix} A^1 - \hat{E}^{21}, & \hat{E}^{12} \\ \hat{E}^{21}, & A^2 - \hat{E}^{12} \end{bmatrix},$$

where A^i is the technology matrix for country i and $\hat{E}^{ji}$ $(= \hat{M}^{ij})$ is a diagonal matrix of the fixed ratios of sectoral exports from country j to country i to sectoral outputs in country i. The weakness of this method of modeling trade flows is suggested by the observation that the matrix Z might have negative elements.

2.3 The analysis of environmental problems

In the early 1970's Leontief and Ford [20], [21] suggested extending the input-output system to account for the generation of environmental pollutants by economic activity and for the resource costs of

Three other papers in the P-S volume concentrate on dynamic input-output models. Volkonskii [38] discusses some properties of such a model under exogenous employment levels and balanced growth assumptions with an exogenous long-run rate of return on capital. Tokoyama, Kobayashi, Murakami and Tsukui [36] embed a dynamic input-output structure in a linear programming model of an open economy in which the terminal value of capital is maximized subject to period by period market clearing constraints and the necessity to hold non-negative levels of foreign exchange. The model avoids the common problem of a tendency to extreme specialization in its production stream only by the introduction of arbitrary divergencies between the foreign exchange value of a unit of each commodity exported and the foreign exchange required to import corresponding units. Ivanov [15] discusses, at a very abstract level and without empirical applications, solutions to another programming model which incorporates the dynamic input-output specification. The period required to attain a desired consumption target is minimized subject to market clearing and minimum consumption constraints during the transition period.

On the evidence of the P-S volume it is difficult to avoid the conclusion that, from the point of view of the empirical analysis of economic policy issues, the dynamic input-output system has proved far less fruitful and flexible than the open static model.

3. EXTENDING THE THEORETICAL STRUCTURE OF THE BASIC LEONTIEF MODEL

3.1 The specification of international trade

The simple input-output model provides an inadequate basis for the modelling of international trade. For single country models the vector

This approach to income distribution is clearly very crude. Changes in ownership patterns (W) and relative factor scarcities reflected in changing relative factor prices (v) are both ignored although in the long-run they would appear to be crucial in the determination of income distribution.

2.5 Dynamic analysis

The final extension of the basic Leontief model which will be considered briefly is the imposition of a dynamic element via a relationship between the demand for investment goods and the rate of change of sectoral output (or capacity) levels. The simplest version of the dynamic input-output model is

$$X_t = AX_t + B(X_{t+1} - X_t) + Y_t \quad , \tag{2.5.1}$$

where B is a matrix of investment coefficients b_{ij} : the input from sector i required per unit expansion in the capacity of sector j . Given the stream of exogenous final demands (Y_t) and an initial value for X_0 , equation (2.5.1) can be solved for a time stream of X_t rather than for a single value of the vector of gross outputs at an (undefined) point in time as is the case for the static input-output model. Solution of (2.5.1) is trivial if B is invertible so that X_{t+1} can be expressed in terms of X_t and Y_t . Even in the more usual case in which B is singular, solution techniques are well known (cf. [17]). Livesey [24] suggests a slightly simpler computational procedure but fails to establish why computational aspects of such a crude accelerator type growth model are still of importance.

pollution abatement. The essentials of the extended model are :

$$X = AX + ES + Y \tag{2.3.1}$$

$$T = PX + QS \tag{2.3.2}$$

$$U = T - S \quad , \tag{2.3.3}$$

where S is a vector of activity levels of pollution abatement sectors and E is a matrix of coefficients e_{ij} : the input from conventional sector i per unit activity in abatement sector j . T is a vector of gross pollutants generated and the matrices P and Q show, respectively, the pollution generated per unit activity in the conventional and abatement sectors. Equation (2.3.3) defines U , a vector of net pollution.

This is the basis of the economic/pollution model for the Netherlands described by den Hartog and Houweling [9]. It emphasizes that pollution abatement is costly both because it absorbs resources and because it generates further pollution. Results from the Netherlands model confirm the empirical importance of accounting for these factors. Cumberland and Stram [8] outline a plan for a complete economic/environmental model which is, sensibly, designed in modular form so that limited analyses can be conducted in advance of the completion of the entire system. Results presented from their pollution generation module (analogous to (2.3.2)) assume $Q = 0$. Thoss [35] also fails to model explicitly the input structure and pollution generation characteristics of abatement sectors. In a heavily constrained linear programming model applied to West Germany he relates the costs of abatement to the level of pollution control in a more rudimentary fashion. The model is used to examine the structure of the economy implied by the maximization of domestic absorption, net of pollution abatement costs, subject to exogenous constraints on the levels of net pollution. Shadow prices on these constraints are then interpreted as the opportunity costs of pollution control.

One problem with all these pollution models concerns the units in which the pollutants (T) are measured. All three papers from the P-S volume present results in physical units - e.g., tons of active ingredients. The policy relevance of such observations is not immediately apparent especially following aggregation (c.f. [8]). Data problems are clearly not to be underestimated in this area but what is required is the reduction of the components of the vector T to some sort of comparable damage units. Ideally these should be value units but physical damage indicators represent a significant advance over the units presented in the papers in the P-S volume. Examples of physical damage units can be found in Dixon et al. [10].

The evidence of the P-S volume is that input-output analysis has been successfully adapted to provide insightful analysis of pollution generation and the costs of pollution control. What is missing from these studies is any analysis of the costs of pollution : that is the benefits of abatement. Without this, no criterion for the establishment of optimal levels of pollution control is available. The analysis must be limited, as in all the contributions to the P-S volume, to an examination of the implications of exogenously imposed pollution control standards. The structure of the input-output approach, especially when embedded in a programming framework, is certainly amenable to the required extension. We might define for example a damage index

$$D = d'U \quad , \qquad (2.3.4)$$

and maximize an objective function which includes D as well as GNP net of pollution control costs. Data limitations rather than the availability of an adequate theoretical structure are the main constraints on such further development.

2.4 Income distribution

The size distribution of income may be important from the point of view of the closure of input-output models in the income-expenditure dimension. If different income groups have different marginal propensities to save or allocate their marginal expenditures differently among commodities, then changes in income distribution will alter the level and composition of final demand. Two papers in the P-S volume [27], [39] investigate these effects. Further discussion of them in this review is postponed until section 3.

The possibility of expanding the input-output system to generate the personal distribution of income endogenously is a separate issue. The assumptions of fixed primary input coefficient technology and exogenous factor prices (i.e., elastic supplies of factors) yield an estimate of the functional distribution of income by sector (F) as

$$F = \hat{v}'L\hat{X} \quad , \qquad (2.4.1)$$

where the notation is as for equation (1.2). That is, the ij^{th} element of F shows the payments accruing to primary factor i in sector j. Weisskoff [39] proceeds from here to map value added by sector (i.e., the column totals of the matrix F) into a matrix S. The ij^{th} element of S shows the income accruing to people in income class i from the activities of sector j. S is computed as

$$S = W\widehat{(1'F)} \quad , \qquad (2.4.2)$$

where the matrix W reflects ownership and workforce patterns of sectors : W_{ij} is the share of value added in sector j earned by members of income group i. Personal income per head by income group can then be generated given data on the size of the income groups.