IMPACT PROJECT

A Commonwealth Government inter-agency project in co-operation with the University of Melbourne, to facilitate the analysis of the impact of economic demographic and social changes on the structure of the Australian economy

Paper prepared as a chapter for

Industrial Economies : an Australian Study (Eds. L.R. Webb and R. Allen)

INTER-INDUSTRY ANALYSIS :

THE ORANI MODEL OF

AUSTRALIA'S INDUSTRIAL

STRUCTURE

by

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General Paper No. G-31 Melbourne March 1981

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

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INTER-INDUSTRY ANALYSIS : THE ORANI MODEL OF

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INTER-INDUSTRY ANALYSIS : THE ORANI MODEL OF AUSTRALIA'S INDUSTRIAL STRUCTURE

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1. Introduction

Inter-industry analysis emphasises the idea that the economy should be viewed as a complete system of interdependent industrial sectors. Individual industries supply produced inputs to each other, they compete for the economy's supplies of primary factors, they compete for sales in domestic markets and they interact with each other via international trade. The implications of industrial interdependence are often crucial to the understanding of the effects of changes in economic circumstances both on particular industries and on the economy as a whole. Consequently, the ability to capture inter-industry effects is of great importance for policy analysis. This chapter is about some methods which have been developed to model industry interactions in order to provide detailed quantitative projections of the effects of policy-relevant changes on the Australian economy.

Two elements are essential for the type of analysis with which this chapter is concerned. The first is a theoretical representation of the ways in which industrial sectors interact with each other. The second is data which reflects the extent of the interactions for the economy of interest. Combining these two elements can be a complex task, especially if the range of interactions which are to be represented is wide and if a detailed industrial disaggregation of the economy is to be retained in the data. Informal methods of analysis are not appropriate

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1. The author wishes to thank Alan Powell and Peter Dixon for their comments on an earlier draft of this chapter. Responsibility for any errors and for all views expressed lies solely with the author.

in this context. Quantitative inter-industry analysis requires the establishment of formal economic models to trace out the implications of the theory and data about sectoral interactions in the economy. ORANI is an example of such a model[1] which has been constructed to represent the contemporary Australian economy and which has been used for the analysis of a variety of current policy issues. These include the effects of changes in the rates of tariff protection against imports, the effects of changes in the exchange rate, the effects of a mineral-export boom, the effects of changes in world commodity prices, the effects of changes in domestic real wages, the effects of macro-economic strategies aimed at reducing unemployment, the effects of changes in the pricing policy for domestic crude oil and the effects of home-price schemes for agricultural export commodities.[2] The ORANI model is the main example which is used in this chapter to illustrate what is to be said about inter-industry analysis.

The remainder of the chapter is organized as follows. Section 2 contains a discussion of the primary sources of interdependence between industries in the Australian economy. It also includes illustrations of why it is important, from the point of view of policy analysis, to account for these interactions. Section 3 contains material about inter-industry modelling. The forerunner of modern inter-industry models, Leontief's open, static, input-output model is outlined in subsection 3.1.

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1. ORANI was developed as part of the IMPACT economic research project. IMPACT was originally sponsored by a number of Commonwealth government agencies and now operates under the joint sponsorship of the Commonwealth Government and the University of Melbourne. The Industries Assistance Commission has taken a leading role among the participating agencies throughout the life of the project. See Powell (1977), Dixon, Parmenter, Ryland and Sutton (1977), and Dixon, Parmenter, Sutton and Vincent (forthcoming).

2. References for these studies are Powell (1977), Dixon, Parmenter, Ryland and Sutton (1977), Dixon, Parmenter and Sutton (1977, 1978a and 1978b), Dixon, Harrower and Powell (1977), Powell and Parmenter (1979), Dixon, Powell and Parmenter (1979), Vincent, Dixon, Parmenter and Sams (1979 and 1980), Dixon, Parmenter, Powell and Vincent (1979), and Parmenter, Sams and Vincent (1980).

In subsection 3.2, ORANI is described and related to the input-output prototype. First, a simple stylized version of the model's theoretical structure is presented (subsection 3.2(a)) followed by some details of the main features of the implemented version (subsection 3.2(b)). The results of an illustrative application of ORANI are presented in section 4. The question analysed in the application is the effects of a 10 per cent increase in domestic steel prices. Some brief concluding remarks are offered in section 5.

2. Inter-Industry Linkages and their Importance for Policy Analysis

A useful way in which to organize data about the structure of an economy is to categorize individual producing units into industries. Many possible criteria, not all independent, might be used in the classification. Similarity of outputs (the "textiles" industry), similarity of input structures ("metal processing"), regional location ("high-rainfall-zone farming") and demand characteristics (the "tourist" industry) are examples. The degree of observed interdependence between industries will not be independent of how industries are classified. In particular the higher the degree of disaggregation which is specified in defining the industrial structure, the more interdependent will the individual industries appear. Interactions between industries defined at a high level of disaggregation - the purchase of yarn by the "weaving" from the "spinning" industry, for example, or the substitution of plastic belts (produced in the "plastic apparel products" industry) for leather belts (produced in the "leather apparel products" industry) - simply cancel out as intra-industry effects at higher levels of aggregation when only a single "textiles" industry and a single "clothing" industry are distinguished.

The observed amount of industrial interdependence is thus sensitive to the nature and extent of industry disaggregation considered. The same sources of interaction between industries in the typical developed market economy are, on the other hand, evident for a wide range of characterizations of the economic structure - from a highly aggregated representation of the economy in terms of just agricultural, mining, manufacturing and service sectors to much more finely disaggregated structures.[1] Two main sources will be identified : direct interactions and interactions implied by constraints on the aggregate operation of the economy.

2.1 Direct interactions

Linkages between industries in the chains of production and distribution of goods and services are the most obvious source of industrial interdependence. Firstly, there are forward and backward linkages arising from the provision and purchase of intermediate inputs. Most industries sell their outputs to other industrial users as well as to final demand. Milk, for example, is sold both for processing in the dairy products industry and also for personal consumption. A change in the demand for cheese will affect the milk producing industry as well as the dairy products industry. Obversely, producers generally require produced inputs to their production processes as well as primary inputs. Production, especially in the manufacturing sector, can be regarded as the addition of value, via the services of primary inputs (land, labour and capital), to inputs purchased from other industries. Steel, for example, can only be produced if supplies of iron ore, coke and electricity are available. Anything which

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1. The Australian Bureau of Statistics (ABS), for example, distinguishes 109 industrial sectors in its Input-Output tables. See ABS (1977). These tables are discussed in more detail in subsection 3.1 below.

affects the availability or the costs of iron, coke or electricity will have implications for the steel industry, and, of course, for steel users.

Investment flows constitute a second form of direct inter-industry linkage. Just as the production of a unit of current output by any industry will usually require the supply of inputs from other industries, so the creation of capital equipment by any industry, via its investment, will create a demand for produced investment goods. Construction-related industries and machinery manufacturers are the most important suppliers of investment goods but the precise mix of commodities embodied in additions to capital stocks varies across investing industries. Investment in rural industries, for example, will require a relatively high proportion of inputs of agricultural machinery. Buildings and computers, on the other hand, will comprise a high proportion of capital inputs for many industries in the service sector (banking, trade, etc.).[1] A shift in the allocation of aggregate investment among industries - stimulation of the tertiary relative to the primary sector, for example - will therefore have direct implications for industries which produce the relevant capital goods.

The third type of direct inter-industry linkage arises from the frictions - both geographical and institutional - which must be overcome in facilitating flows of commodities from their producers to their users. The services of various trade (wholesale, retail, insurance, etc.) and transport industries are usually required, not as direct inputs to the production or investment processes of other industries, but for the transfer

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1. Data on the commodity composition of the capital stocks of Australian industries have been compiled within the IMPACT project. See Hourigan (1980).

of goods and services between producers and purchasers. The corresponding costs can then be viewed as constituting a mark-up between the price received by the producer and the price paid by the purchaser. Clearly, the fate of industries producing the mark-up services is heavily dependent on the level of activity in the economy generally and on the pattern of demand for commodities.

The direct interactions between industries which have been identified in this subsection can be represented systematically in input-output accounts such as those produced for the Australian economy by the Australian Bureau of Statistics. Input-output accounts are the most important part of the data base required for inter-industry analysis at an empirical level. The structure of these accounts and their role in inter-industry models is discussed in detail, with special reference to the Australian tables, in section 3 below.

2.2 Interactions via aggregate constraints

Even where industrial sectors are not directly linked by inter-industry flows of commodities, they will still be interdependent since they are components of an economic system which is itself subject to various aggregate constraints. The first such constraint is the limitation on available supplies of primary resources (land, labour and capital funds). Whilst this limitation often applies to the economy as a whole, it need not apply to individual industries. In the long run at least, primary factors are not industry specific. Labour of the same skill or occupation is often employed in a variety of different industries so that, even in the short run, much of the labour force is readily transferable between industries. In the long run, the incidence of natural wastage and replacement and the possibility of retraining increase the industrial mobility of labour still further. Capital might be regarded as industry-specific in the short run - in fact, neoclassical economics usually defines the short run as a period in which each industry's capital stock is fixed. In the long run, however, the processes of investment and depreciation imply potential mobility between industries of the capital stock available to the economy as a whole, even if individual items of capital equipment, once built, can be used in only a single industry. Similarly, land, in the long run at least, can be transferred between agricultural and other industrial uses and, within each of these major sectors, can be used for a variety of different enterprises.

For many purposes, then, it will be appropriate to view the supply of primary inputs as fixed for the economy as a whole, but as variable to individual industries. Industries interact because they are competing for the economy's pool of scarce resources. Some rationing device is required to allocate the scarce inputs among the industries. In a market economy prices generally perform this role. An increase in the world demand for wheat, for example, will tend to bid up rentals on agricultural land, thus increasing the costs and reducing the profitability of other forms of agricultural production. Similarly, a shortage of skilled tradesmen, say, will tend to increase the wage commanded by that occupation, increasing the costs of all industries which employ it. It may be necessary in these contexts to interpret the notion of the rationing "price" generously to include the cost to the user of common forms of non-price rationing. Institutional rigidities in the labour market might prevent the wage paid to the scarce skilled tradesman from rising but potential employers may find it more difficult and time-consuming to hire additional workers in this category. Similarly, in an investment boom, finance may be more difficult to acquire even if interest rates do not rise. Lenders may just become more selective. This, for example, is the common experience in the market for housing loans.

Whilst the characterization of the economy as subject to constraints on aggregate supplies of industrially mobile primary factors is often appropriate, the constraints need not always be binding even at the aggregate level. A situation of general underemployment of labour, the most obvious example in the contemporary Australian economy, removes the short-run interdependence of industries via the labour market. Where slack labour market conditions prevail general increases in the demand for labour can be satisfied without bidding up labour costs. In fact, during most of the 1970's when these conditions prevailed in the Australian labour market, the institutional phenomenon of wage indexation provided an alternative form of labour-market interdependence between industries. Under the indexation system money wage rates, which account for about 50 per cent of total domestic costs, are effectively tied to the domestic consumer price index so that price shocks originating in any part of the economy can have widespread repercussions throughout the whole economy. The effects will be most obvious in those industries whose selling prices are fixed more or less independently of their costs. The prime examples in the Australian economy are export industries which sell primary products (agricultural and mineral products for instance) on fairly competitive world markets. Import-competing industries are also constrained in raising their selling prices by foreign competition. Anything which stimulates price rises in the domestic economy (tariff increases, for example) will be transmitted, mainly via an increase in labour costs, into a cost-price squeeze on those industries which depend heavily on international trade. Conversely, reductions in domestic prices relative to world prices will result in increased profitability for the trading sectors.

Alternatives to the view that industries are tied together via aggregate constraints on factor markets are also possible in the case of the capital market. To the extent that the world capital market allows free international flows of investment funds, the supply of funds to the domestic economy might not be constrained by domestic savings. If Australia can be regarded as operating as a small borrower in an open capital market, an elastic supply of funds to the economy might be a better working assumption than the fixed-pool view. In fact, it is likely that the degree to which Australia can tap international capital sources is itself industry-specific. It is often argued, for example, that mineral development schemes do not compete for funds with the rest of the economy because they are able to attract international capital inflow which would not otherwise accrue.

So far this subsection has dealt with interdependence between industries on the supply side, that is with reasons why the operations of one industry might affect the costs of other industries. Parallel connections can be identified between industries on the demand side. Whenever users regard the products of different industries as substitutes, or whenever some complementarity in use exists between the products, the prospects of a number of industries may be significantly affected by user reactions to changes originating in a single industry. Again, prices are the key transmission mechanism. The rise in oil prices of the mid-1970's has produced clear examples. On the one hand the prospects of alternative energy-producing sectors, coal for instance, have improved as consumers substitute against relatively more expensive oil. On the other hand, industries whose products are close complements with oil-based energy (large automobiles, for example) have been adversely affected. Note once again that these demand-side interdependencies can be interpreted as resulting from an aggregate constraint on the economy which does not firmly constrain individual industries within it. In this case it is the overall size of the consumption market which is constrained, although the commodity composition of the consumers' basket of goods is variable.

For a small, open economy which, as in the case of Australia has a comparatively heavy dependence on international trade, the balance of payments constitutes a third aggregate constraint which interposes important linkages between industries. In the long run, the economy must balance its balance of payments so that anything which improves the net foreign-exchange-earning ability of one part of the trading sector will tend to harm the prospects of other exporters and import-competing industries. Gregory (1976) has emphasized the importance of the foreign-trade constraint in his analysis of the effects on the Australian economy of the mining boom of the late 1960's and early 1970's. He pointed out that the increased foreign-exchange earnings of the mining industries during this period generated a move towards surplus in the Australian balance of payments which exerted pressure for upward revaluation of the Australian exchange rate. To the extent that this pressure was resisted, the improvement in the balance of payments (via its augmentation of the domestic money supply, for example) would have raised the domestic inflation rate relative to the rate of increase in the world prices of traded goods. In either event the Australian dollar values of internationally traded goods would decline relative to domestic prices of non-traded goods and thus relative to domestic production costs. The change in relative prices imposes a cost-price squeeze on the import-competing and exporting industries.

Once again, the above analysis depends upon a constraint operating on the economy generally but not on any industry in particular. To put it crudely, the economy must balance its international payments so that if one industry is put in a position whereby it earns (or saves by import replacement) more foreign exchange than formerly, other industries must be forced to compensate by earning (or saving) less foreign exchange than formerly. Once again price changes (in this case possibly including a change in the price of foreign exchange) are important in the explanation of the mechanism whereby the constraint enforces the implied interdependence between industries.

2.3 The importance of inter-industry analysis

In the previous two subsections, several forms of inter-industry linkages were described. The purpose of this subsection is to demonstrate, from the point of view of policy analysis, the importance of analytical methods which account for the general interdependence of individual sectors of the economy. We give examples of a wide variety of policy issues where the use of an inter-industry method can at least broaden the range of insights gained from analysis and can often modify severely, or even reverse completely, conclusions which might be drawn on the basis of analytical tools which fail to account for the types of linkages described above. The examples are drawn from the spectrum of issues which have been addressed in the ORANI applications papers referred to in section 1.[1]

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1. See page 2, including footnote 2.

The first example is macro-economic policy, an area in which discussion is conventionally conducted in terms only of aggregate descriptions of the economy : aggregate employment, the overall price level, gross domestic product, etc.. Alternative macro-economic policy instruments, however, are seldom neutral in their effects across industrial sectors of the economy. Moreover, since the economic performance of geographical regions in the economy is intimately related to the industrial structures of the regions, the regional impact of macro policies is also unlikely to be neutral. To trace these industrial and regional consequences of macro policy, to which policy makers will not usually be indifferent, a method which models the industrial structure of the economy and of its regions will be required.

The importance of these issues in the current macro policy debate has been emphasized by Dixon, Powell and Parmenter (1979) in a study in which the ORANI model is used to investigate the structural implications of alternative methods of increasing domestic employment. A key result of the analysis is the contrast between the industrial effects of Keynesian demand stimulation and the neoclassical alternative of attempting to generate employment increases from the supply side by reducing the real costs of employing labour. The former (Keynesian) policy, whilst it yields some increase in aggregate employment, is shown to stimulate primarily sectors of the economy which are not involved in international trade but to reduce employment in many of the export industries and to generate an adverse movement in the balance of trade. The explanation is that international competition places a constraint on the extent to which exporters and import-competing industries can increase their selling prices. Attempts by firms in these industries to pass on domestic cost increases generated by the inflationary effects of demand stimulation will generally lead to sales losses. On the other hand, the neoclassical policy of reducing wage costs, which also increases aggregate employment, has its greatest stimulatory effects on the internationally trading industries and causes an improvement in the trade balance. Non-trading industries do not stand to gain much from domestic cost reductions since the size of the domestic market is more or less fixed and their selling prices tend to be tied to their costs. Exporters and import competitors are able to take advantage of the fall in domestic costs by increasing their market shares at the expense of foreign competitors.

The regional counterparts of this key contrast are also reported in Dixon, Powell and Parmenter (1979). Demand stimulation is shown to be less beneficial to employment in Queensland and Western Australia than it is to employment in the economy as a whole. The reason is that the economies of these two states exhibit relatively heavy orientation towards export-related activities. Domestic cost reductions, in contrast, are particularly favourable to these states on account of the improvement generated, by the cost reductions, in the international competitiveness of the exporters.

On the basis of these results, Dixon, Powell and Parmenter suggest a macroeconomic policy package combining both demand stimulation and reductions in real wage costs. The package is designed to increase domestic employment without damage to the balance of trade and to give a well balanced stimulation of activity across the industrial and regional structures of the economy. The use of an analytical tool which accounts explicitly for industrial interdependence highlights the structural implications of macro policy options and facilitates the analysis of the effects of domestic policy changes on the international trade account.

The sectoral effects of changes in economic circumstances, either policy-induced or beyond the control of the economy's managers, are more conventionally emphasized in the context of microeconomic policy. Even where the primary focus of interest is the fate of a particular industry as opposed to the industrial structure in general, it is often the economy-wide view which is the most appropriate perspective for analysis. Secondary effects generated by the interdependence of the industry of interest with the rest of the economy can be important, or even predominant, in the total impact of change in conditions facing the industry. These secondary effects may be difficult to capture using a single-industry approach. Gregory's analysis of the effects of a mineral-export boom [1] provides a good example of the problem. An interesting implication of his analysis is that feedback effects via the impact of the boom on the balance of payments are important in understanding the net effects of the boom <u>on the mining sector itself</u> as well as on the other trading sectors in the economy. The pressure for revaluation of the Australian exchange rate (or, alternatively, for an increase in the domestic inflation rate relative to world prices) generated by the increased foreign exchange earnings associated with the boom will lead to a deterioration of the competitive position of <u>all</u> the trading sectors including mining. The lesson is that an analysis of the consequences of the mining boom which ignored the balance of payments effects would be likely to overstate the stimulating effects on the mining sector. Dixon, Parmenter and Sutton (1978a), using ORANI, have provided an analysis of the balance of payments effects of the mining boom at a greater level of industry disaggregation than was available to Gregory. The study includes a projection of the adverse secondary effects of the boom on pre-existing mining activities.

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1. See Gregory (1976) and page 10 above.

A further example of the importance of taking an economy wide view in analysing the fate of even an individual industry under the impact of a change in the economic environment (this time policy-induced) arises from criticisms of the use of effective rate of protection measures as indicators of the resource allocation effects of tariff protection. The effective rate measures the impact of the tariff structure on value added in an industry.[1] It accounts for the direct effects on the industry's costs of tariffs on its produced inputs as well as for any increase in the industry's revenues allowed by tariffs on its outputs. Although the importance of direct inter-industry linkages in industries' cost structures is, therefore, accommodated in the effective rate, a whole range of other indirect effects of tariff protection are ignored. In particular, no account is taken of the impact on exporting sectors of the increased domestic cost level associated with the existence of tariff protection. Suppose that the industry we are studying has a relatively high effective rate of protection - a high nominal tariff protecting its output and minimal usage of highly protected inputs - but produces a commodity which is almost exclusively used as an input to an important exporting industry. In such a case the ranking of the industry against others in the economy according to its effective rate of protection would almost certainly give a misleadingly favourable impression of the extent of the relative advantage given to the industry by the tariff system. A good example of an industry with some of these characteristics in the Australian economy is agricultural machinery. Although general protection for the manufacturing sector may have increased the industry's share, vis-à-vis imports, in its selling market, the adverse effect of the tariff structure on the competitive position of the exporting customer will have reduced the overall size of the market. Meltzer (1980)

1. See Corden (1971).

has studied the relative rankings of industries in the Australian economy by effective rates and by the resources allocation effects of the tariff system as computed in the ORANI model. Dixon, Parmenter, Ryland and Sutton (1977, chapter 4) also produce evidence indicating the importance of the economy wide view in the study of tariffs.

These examples are designed to indicate that an economy-wide approach to policy analysis may be necessary even in assessing the effects of changes in the economic environment on the directly affected industries. A more fundamental point is that policy analysis might well lead to false conclusions if it is confined only to consideration of the implications of changes for the directly affected industries. The relationship between tariff protection and domestic employment is an excellent example. It is often argued that tariff protection is necessary to protect employment in the Australian economy. Obvious implications of this view are that tariff cuts, undertaken for resource allocation reasons perhaps, would cause unemployment and that increases in protection are an effective means available to reduce unemployment. It is not difficult to show that protection might sustain employment in the protected industries themselves but to extrapolate from that to the conclusion that tariffs are'employment-generating from the point of view of the economy as a whole ignores possible indirect effects on employment in other sectors. Tariffs raise the domestic cost level, especially when real wages are kept fixed by a system of wage indexation. Industries which sell prodominantly to the domestic market without import competition will usually be able to pass on cost increases and maintain their levels of activity. Industries which engage heavily in international trade on the other hand, especially export industries, often face selling prices which are more or less fixed on world markets. The effect on these industries of an increase in the general level of protection is to impose a cost price squeeze on them which may cause reductions in their levels of activity and employment. Once these indirect effects are considered, it is no longer obvious, *a priori*, whether tariff protection has beneficial or adverse effects on aggregate domestic employment. Studies of the short-run effects of across-the-board tariff changes on the Australian economy using ORANI (Dixon, Parmenter, Ryland and Sutton (1977, chapter 4) and Dixon, Powell and Parmenter (1979)) have indicated that changes in employment in the non-protected trading sectors will approximately offset the changes in the protected sectors.

3. Inter-Industry Models

The inter-industry approach to economic analysis demands that the analyst should know a lot about the whole economy in order to be able to grasp the implications of changes in small parts of the system. In the previous section it was argued that indirect effects, implied by the existence of a variety of linkages between industries, may be more important than direct effects in assessing the consequences of developments in the economy. Accounting for these indirect effects entails focussing on the details of how individual industries are linked to the rest of the economy. Making the *ceteris paribus* assumption (that product-demand and input-supply curves facing an industry do not shift, for example) and concentrating on a single sector in isolation is inadequate.

Inter-industry models of real economies attempt to capture, in a manageable form, some of the important interactions which are evident between sectors. Such models are generally built up as follows. First, assumptions are made about the behaviour of the agents (producers, consumers, etc.) who are to comprise the simplified representation of the economy. Assumptions must also be made about the technological and/or institutional constraints (production functions, utility functions, market structures, etc.) within which the agents are to operate. From all this, the theoretical structure of the model is derived using standard methods of economic theory. Producers, for example, may be assumed to minimize the cost of producing any given level of output. They may be assumed to be price takers in the markets in which they buy their inputs and to be constrained by some postulated production function which describes the technology for combining intermediate and primary inputs to produce their particular outputs. From this we can derive the producers' demand functions for inputs; typically functions of output levels and input prices. Values for the parameters of the theoretical structure (input coefficients, demand elasticities, substitution parameters, etc.) must then be assigned on the basis of data which represent, for some base year or over some historical period, the operation of the economy to which the model is to be applied. The result is a system of equations which can be solved for projected values of some of its variables (the endogenous variables) given pre-specified values for other variables (the exogenous variables). A typical inter-industry model, for example, might be used to give projected values for industry-output levels given values for some final-demand variables.

In this section the construction and implementation of inter-industry models will be illustrated using two examples. The first, and the simplest, is the open-static input-output model first formulated by Leontief (1937). This is of interest because it is the prototype in this field of analysis and because input-output studies of various types are still commonly employed in the analysis of policy problems.[1] The basic features of the input-output model and its main limitations are discussed in subsection 3.1. A much more elaborate inter-industry model, which is publicly documented and which has been implemented using Australian data, is the ORANI model. Subsection 3.2 contains a description of ORANI which attempts to show how modern developments in economy-wide modelling have expanded the scope of the input-output prototype.

3.1 The prototype : the open static input-output model

The basic input-output model is a device which accounts for the interdependence between industries which arises from the existence of commodity flows between them. That is, it encompasses some of those forms of interdependence which were categorized as "direct interactions" in Section 2. An important shortcoming of the model from the point of view of policy analysis is that it cannot accommodate interactions of the second type identified in Section 2, i.e., interactions via aggregate constraints on the economy. The reason for this shortcoming is to be found in the very limited role which commodity and factor prices have in the input-output model.

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1. See, for example, the proceedings volumes of the regularly held international input-output conferences. Brody and Carter (1972) and Polenské and Skolka (1976) are two of the more recent.

In part (a) of this subsection the theoretical structure of the open static input-output model is reviewed. Part (b) of the subsection is about input-output tables, the fundamental data sources for all inter-industry models. As well as a general description of the Australian input-output tables, an outline is included of how the data required for the input-output model (described in part (a)) can be constructed from an aggregated version of one of the Australian tables. Finally, part (c) of the subsection expands upon the limitations of the basic input-output model as a policy analytic tool.

(a) Theoretical structure

Input-output models are essentially models for determining industries' output levels on the basis of the demand for output. Each industry is assumed to be the sole producer of a single product. In computing demand, the model recognizes that output is used not only in final demand (household consumption, government consumption, capital formation and exports) but also as inputs into industries' production processes. The simplest version of such a model is sufficient for the purposes of this section. It is a model in which international trade is ignored[1] and which is open in the sense that all elements of final demand are exogenous, i.e., not determined within the model. The model is static : all commodity demands depend only on output in current periods or else are exogenous.

Construction of the open static input-output model begins with the assumption that producers are efficient in the sense that they minimize the total cost of producing any output level. The key technological assumption of the model is summarized in the fixed-coefficients production function

1. Problems associated with the introduction of international trade are considered below in subsection 3.1(c), part (ii).

$$X_j = \underset{\{i,\ell\}}{\text{Min}} \left(\frac{X_{ij}}{A_{ij}}, \frac{F_{\ell j}}{L_{\ell j}} \right), \qquad \begin{array}{l} i, j = 1, \ldots, n, \\ \text{and } \ell = 1, \ldots, m ; \end{array} \tag{3.1}$$

where X_j is the output of industry j , X_{ij} is the input from industry i to the production process of industry j ; $F_{\ell j}$ is the input of primary factor ℓ to the production process of industry j , A_{ij} and $L_{\ell j}$ are fixed coefficients showing, respectively, the minimum input from industry i and of primary factor ℓ required per unit output of industry j , n is the number of industries (and commodities), and m is the number of primary-factor categories.

Equation (3.1) indicates that fixed minimum amounts of all inputs (given by the A_{ij} and the $L_{\ell j}$) are required in order to produce a unit of output in industry j . This assumption rules out any possibility for producers to economize in the use of one input by using more of other inputs, i.e., no substitution between inputs is allowed.

So long as inputs have positive prices, cost-minimizing producers will employ, per unit output, just the minimum requirements given in equation (3.1) of all inputs. Producers' demand functions for produced and primary inputs are therefore given, respectively, by equations (3.2) and (3.3), i.e.,

$$X_{ij} = A_{ij} X_j , \tag{3.2}$$

and

$$F_{\ell j} = L_{\ell j} X_j , \qquad \begin{array}{l} \text{for all } i,j = 1, \ldots, n, \\ \text{and } \ell = 1, \ldots, m . \end{array} \tag{3.3}$$

Note that input demands in equations (3.2) and (3.3) depend just on industries' output levels. In particular, input prices do not enter the demand functions since technology is assumed to allow no substitution between inputs.

Equation (3.2) fixes intermediate demand for industries' outputs. Final demand is as yet undetermined. In the simplest version of the input-output model, final demand for the output of each industry (Y_j) is determined entirely outside the model, i.e.,

$$Y_j = \bar{Y}_j \ , \qquad j = 1, \ldots, n \ , \tag{3.4}$$

where $\bar{Y}_j$ is the exogenously given level of final demand for the output of industry j . One alternative is to project parts of the required final demand from more naturally exogenous data by further use of input-output methods. For example, demand for investment goods (i.e., demand for produced inputs to capital formation in other industries) will constitute some proportion of total final demand. If aggregate levels of investment by investing industry are taken as exogenous, demand for investment goods can be generated as[1] .

$$Y_j^I = \sum_{i=1}^{n} B_{ji} \bar{Z}_i \ , \qquad j = 1, \ldots, n \ , \tag{3.5}$$

where Y_j^I is the demand for investment goods produced by industry j , $\bar{Z}_i$ is the exogenously given level of investment in industry i , and the B_{ij} are technological coefficients (analogous to the A_{ij}) showing the input from j required per unit capital formation in industry i .

The final step in the construction of the basic input-output model is to impose a market-clearing constraint for each industry's output. That is

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1. Note that equation (3.5) implies industry demand functions for investment goods of the same form as their demand functions for intermediate inputs (equation (3.2)). These can be derived on exactly the same basis as were the intermediate-demand functions, i.e., by assuming that investors are cost minimizers and that they are constrained by fixed-coefficient technology for capital formation.

$$X_i = \sum_{j=1}^{n} X_{ij} + Y_i \quad , \qquad i = 1, \ldots, n \, . \tag{3.6}$$

Equation (3.6) requires that the output of industry i is just equal to the sum of intermediate and final demand for it.[1] By substituting equations (3.2) and (3.4) into equation (3.6), the input-output model can be solved to give industry output levels as a function of exogenous final demand. In matrix notation we have

$$X = AX + \bar{Y} \quad , \tag{3.7}$$

and

$$X = (I - A)^{-1} \bar{Y} \quad , \tag{3.8}$$

where X is an $(n \times 1)$ vector of the X_i , $\bar{Y}$ is an $(n \times 1)$ vector of the $\bar{Y}_i$, A is an $(n \times n)$ matrix of the input-output coefficients, A_{ij} , and I is the identity matrix.

The information about inter-industry connections which is accounted for in this version of the input-output model is encapsulated in the Leontief inverse matrix $(I - A)^{-1}$ which appears in equation (3.8). The typical, ij^{th} , element of this matrix shows the total amount of intermediate inputs of type 'i directly and indirectly required per unit delivery to final demand of the output of industry j . It accounts not only for inputs of i used directly in the production process of j (as shown in the ij^{th} element of the matrix A) but also for the successive rounds of indirect usage of i by j via its other produced inputs. If input i is steel, for example, and industry j is the motor vehicles industry, the the ij^{th} element of the Leontief inverse matrix accounts not only for the

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1. Stock formation can, of course, be included in final demand.

steel used directly in the manufacture of motor vehicles but also for the steel used in the manufacture of other inputs (metal products, say) supplied to the motor industry and for the steel embodied in all the intermediate inputs purchased by the suppliers of metal products, etc., etc..

Equation (3.8) gives projections of the implications of alternative final demand assumptions for the gross output levels of the industries distinguished in the model. On the basis of the solution to (3.8) and using (3.3) projections of aggregate demands for primary factors can easily be generated as

$$F_\ell = \sum_{j=1}^{n} L_{\ell j} X_j , \qquad \ell = 1, \ldots, m , \tag{3.9}$$

or in matrix notation

$$F = LX , \tag{3.10}$$

where F is an $(m \times 1)$ vector of the F_ℓ , i.e., the aggregate demand for factor ℓ , and L is an $(m \times n)$ matrix of the factor input coefficients, $L_{\ell j}$. Equations (3.8) and (3.10) can be used both as policy-analytic tools to project the implications for industry structure and factor demand of various hypothetical final-demand scenarios and as means of extending the range of economic forecasts, provided that independent forecasts of final demand can be made.

Equations for the determination of the prices of industries' outputs can be appended to the input-output quantity model (i.e., equations (3.8) and (3.10)). The key assumption is that prices are equal to unit costs. That is

$$P_j = \sum_i A_{ij} P_i + \sum_\ell L_{\ell j} W_\ell \ , \qquad (i,j = 1, \ldots, n, \ \ell = 1, \ldots, m) \ , \tag{3.11}$$

where P_j is the unit price of the output of industry j and W_ℓ is the unit price of primary factor ℓ. Factor prices are taken as exogenous, i.e.,

$$W_\ell = \bar{W}_\ell \ , \qquad (\ell = 1, \ldots, m) \ , \tag{3.12}$$

and the solution for output prices is given, in matrix notation, by solving

$$P' = P'A + \bar{W}'L \ , \tag{3.13}$$

which yields

$$P' = \bar{W}'L \ (I - A)^{-1} \ , \tag{3.14}$$

where P' and $\bar{W}'$ are respectively $(1 \times n)$ and $(1 \times m)$ vectors of output and primary-factor prices.

The input-output pricing equation (3.14) gives each output price as the sum of value added generated in the production of all inputs used, directly and indirectly, in the production of a unit of output by the relevant industry. The pricing equation can be used to project the effects on commodity prices of changes in primary-factor prices, which are taken as exogenous. One important implication is that factor intensity is most meaningfully defined in an inter-industry context. The relative effects across output prices of an increase in wage rates, for example, in the input-output pricing model is shown to depend not only on the relative importance in industries' cost structures of labour directly used (as shown by the elements of the matrix L) but also on the amount of labour embodied in the intermediate-input costs of the industries.

(b) Data requirements : input-output tables

The basic open static input-output model is summarized by equations (3.8), (3.10) and (3.14). Its data requirements are the matrices A and L which describe, respectively, the pattern of intermediate inputs classified by industry of supply, and the pattern of primary inputs, used for current production by the model's industries. These requirements can be met from tables of input-output accounts which give a detailed picture of the flows of produced goods and services and of primary factor services occurring in the economy of interest during some historical period : usually one national accounting year. Input-output accounts represent a disaggregation of national (income and expenditure) accounts in which intermediate transactions are not netted out.

The compilation of input-output accounts was pioneered in the United States by Wassily Leontief. In 1936 he published an input-output table for the U.S. which distinguished 41 industry-sectors (Leontief, 1936). The pioneer of input-output accounting in Australia was Burgess Cameron who published a 150 commodity by 79 industry table for the year 1946-47 (Cameron, 1957), and smaller tables for 1953-54 and 1956-57 (Cameron, 1958 and 1960). More recently, sets of input-output accounts have become regular items on the publication lists of most government statistical agencies.[1] Official input-output accounts described as "experimental"[2] were first published for Australia in 1964 (CBCS, 1964). They referred

1. See United Nations (1972).

2. CBCS (1973, p. 3).

to the year 1958-59 and distinguished 35 industries. Since then complete sets of input-output accounts have been published for 1962-63 distinguishing 105 industries (CBCS, 1973), and for 1968-69, distinguishing 109 industries (ABS, 1977). The last of these adopted the Australian Standard Industry Classification (ASIC, see CBCS, 1969) as the basis for its industry classification and drew heavily on data collected for the integrated economic censuses. The Australian Bureau of Statistics (ABS) plans to continue with the ASIC-based, input-output classifications so that in the future the accounts will be comparable over time. To date a preliminary bulletin for the 1974-75 input-output accounts has appeared (ABS, 1979) with the full set of accounts for that year due later in 1980. [1]

In Table 3.1 is reproduced a simple nine-sector aggregation of one of the tables from the 109-industry input-output accounts for 1968-69 published by the ABS. This aggregated table will be used to illustrate some general features of input-output accounting and to show how the matrices A and L, required by the input-output model, can readily be constructed from input-output data.

The flows shown in Table 3.1 are all denominated in units of millions of \$A at 1968-69 prices. The table is described as "gross" since it includes flows representing usage by industries of commodities produced within their own industry classifications. These intra-industry flows are shown by the elements on the main diagonal of the sub-matrix formed by the first nine rows and columns of the table. Aggregation of the original 109-industry table to only 9 sectors has produced

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1. An obvious problem with the Australian input-output accounts from the users' point of view has been the age of the data at its time of publication The 1968-69 tables, for example, did not appear until eight years after their reference point. Recent changes in the method of compilation within the ABS are promised to result in more timely publication in future. As is the practice in some overseas countries, it is proposed to move to the production of an annual series of input-output tables for Australia. See Gretton and Cotterell (1979).

Table 3.1 : 9-Sector Input-Output Table for Australia 1968 - 69

(Gross Flows at Basic Values with Direct Allocation of Imports, $m)

INPUTS	USERS																
	1 Primary Sector	2 Mining	3 Food Processing, etc.	4 Textiles Clothing F'wear	5 General Manuf.	6 Public Utilities	7 Construction	8 Trade Transprt Communic^n	9 Finance Services	10 Total Intermed. Demand	11 Final Consump^n (Private)	12 Final Consump^n (Public)	13 GFCE(a)	14 Increase in Stocks	15 Exports	16 Total Final Demand	17 Total Demand
1 Primary Sector	295.6	15.4	1580.3	98.8	84.0	0.6	0.2	7.9	4.4	2087.2	379.3	12.4	-	342.9	923.4	1657.9	3745.1
2 Mining	0.4	166.9	9.5	1.1	459.7	52.5	55.6	18.0	7.6	771.2	8.1	11.5	24.3	12.7	321.3	378.0	1149.1
3 Food Processing etc.	134.3	0.0	741.6	5.9	38.0	0.1	1.1	8.3	91.7	1021.0	2479.5	-	5.9	51.6	692.5	3229.5	4250.5
4 Textiles, Clothing, Footwear	5.7	0.2	5.8	482.0	80.1	-	1.2	19.8	89.9	684.7	868.6	-	2.7	30.2	113.4	1014.9	1699.6
5 General Manufacturing	348.9	120.8	286.1	123.5	3811.7	40.0	1857.6	909.4	1041.3	8539.1	1506.6	-	1613.8	192.1	749.6	4062.0	12601.1
6 Public Utilities	41.8	32.9	35.1	15.5	192.1	23.6	22.1	46.8	351.5	761.4	366.8	25.1	3.0	0.7	0.3	395.9	1157.3
7 Construction	43.3	9.2	20.7	10.0	70.4	39.9	71.0	155.1	499.3	918.9	-	-	3997.8	-	-	3997.8	4916.7
8 Trade, Transport, Communication	280.8	70.2	302.9	55.9	758.3	42.7	534.2	667.2	892.9	3605.0	4361.9	13.2	816.0	8.2	814.0	6013.5	9618.2
9 Finance, Services	65.2	37.3	202.3	84.3	649.8	72.7	132.7	1212.8	3027.4	5484.5	4675.6	3274.6	232.1	0.1	85.3	3267.7	13752.3
10 Total Intermediate Inputs	1216.1	452.9	3184.3	876.8	6145.9	272.1	2675.6	3045.3	6006.0	23872.9	14646.4	3336.8	6695.6	638.4	3699.8	29017.0	52889.9
11 Wages, Salaries, Supplements	403.0	319.8	565.6	434.8	3022.9	301.1	1463.0	3342.3	4077.0	14029.5	-	-	-	-	-	-	14029.5
12 Gross Operating Surplus	1936.0	344.4	375.9	152.7	1733.9	548.6	524.0	2590.0	2498.0	10703.5	-	-	-	-	-	-	10703.5
13 Indirect Taxes	123.6	5.7	3.3	10.2	144.7	29.3	80.0	278.1	546.5	1221.4	1057.9	-	57.0	-8.5	13.3	1119.7	2341.1
14 Sales by Final Buyers	0.0	0.1	-	0.2	92.6	-	-	-	1.1	94.1	7.5	-	-119.6	9.0	8.9	-94.2	0.0
15 Complementary Imports	1.4	0.3	16.9	10.4	87.3	-	-	110.4	149.6	376.2	73.1	-	-	0.9	0.1	74.1	450.4
16 Competing Imports	65.1	25.9	104.5	214.5	1375.7	6.2	174.1	152.2	474.0	2592.2	697.7	0.6	654.0	52.6	182.4	1587.3	4179.5
17 Total Inputs	3745.1	1149.1	4250.5	1699.6	12601.1	1157.3	4916.7	9618.2	13752.3	52889.9	16482.7	3337.4	7287.0	692.5	3904.4	31704.0	84593.9

(a) Gross Fixed Capital Expenditure

Source : Agregated from ABS, 1968-69 Input-Output accounts. The mapping between the aggregate industry classification and the 109-industry classifications used in the ABS accounts is as follows (the ABS codes included in each of the 9 aggregated industries is given in brackets following the aggregate industry number) : 1 (1.01-4.30); 2 (11.01 - 16.10); 3 (21.01 - 22.01); 4 (23.01 - 24.03); 5 (25.01 - 34.05); 6 (36.01 - 37.01); 7 (41.01 and 41.02); 8 (46.01 - 55.01); 9 (61.01 - 99.01).

quite high values for the diagonal elements, especially in sectors 4 (Textiles, Clothing and Footwear) and 5 (General Manufacturing) which contain industries forming integrated chains of production. Sector 4, for example, aggregates industries which produce yarns with industries producing cloth and finished garments while sector 5 contains the chain of metal processing and the manufacture of metal products. Clearly, in a table with a finer level of industry disaggregation intra-industry flows would account for a much smaller percentage of the total value of transactions. A common alternative form of input-output table is the "net" table in which all intra-industry flows are omitted.[1]

Each of the first nine rows of the table shows the total sales of the corresponding (row) industry. In positions 1 - 9 of the i^{th} such row are the sales by the i^{th} industry of current inputs to other industries. In positions 11 - 15 are its sales to final demand. Thus row 1 indicates that in 1968-69 the primary sector made total sales worth \$A3745.1 m. of which, for example, \$A1580.3 m. was sold to the food processing sector and \$A379.3 m. to private final consumption. Rows 11 and 12 contain the value of sales of primary factor services, row 11 accounting for the returns to labour and row 12 for returns to non-labour factors, mainly capital. Thus row 11 shows that the total value of labour services in 1968-69 was \$A14029.5 m., of which \$A403.0 m. was sold to the primary sector.[2] Row 13 shows the net indirect taxes (i.e., taxes less subsidies) levied on commodity and

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1. Measurement and valuation problems can clearly arise with respect to intra-industry flows expecially if these include flows between establishments in the same enterprise. The ABS publish both gross and net tables.

2. Note that under ABS conventions all primary-factor flows are allocated to the industry columns. Factor services are not shown as absorbed directly into capital formation, for example, but only indirectly via producers of investment goods.

factor flows. Most of this is commodity taxes although some production taxes such as the payroll tax are also included. The entry in column 5 of row 13 shows, for example, that the total value of indirect taxes levied on all the current purchases of the general manufacturing sector was $A144.7 m. Row 14 accounts for purchases and sales of second hand assets, the latter being shown as negative entries in the GFCE column.[1] Finally, the sales of imports are shown in rows 15 and 16. Imports which compete closely enough with domestic products so that they could be classified to the domestic industry classification appear in row 16 and imports for which it is judged that no equivalent domestic producing industry exists are in row 15. For both types of import, duty is included in the value of these flows. All imports are allocated directly to the column of their users in Table 3.1. Thus, the elements 1 - 9 of the imports rows show the landed duty paid value of imports, non-competing and competing respectively, sold to the nine industries as inputs to current production. Similarly, the value of imports absorbed into final demand, is shown in columns 11 - 15.[2]

Each column of the input-output table shows the purchases of the relevant (column) industry or final demand category. In the

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1. Note that with the "basic" valuation convention employed for Table 1 (see below) the positive and negative entries cancel exactly.

2. Competing imports can alternatively be shown in matrix form. The competing imports matrix corresponding to Table 3.1 would have 9 rows and a column for each industry and final demand category. The typical, ij^{th}, element of such a matrix would show the basic value of imports classified as competing with the output of domestic industry i and purchased by domestic industry or final demand category j. Input-output tables described as allocating competing imports indirectly have such an imports matrix added to the domestic flows section of the table. The j^{th} element of the i^{th} industry row of such a table shows, therefore, the flow of the output of domestic industry i plus the flow of competing imports of the i^{th} category going to the j^{th} user. The ABS publishes tables with both treatments.

9-industry columns, industries' purchases of inputs to current production only are shown. Purchases for capital-formation purposes are aggregated in the GFCE column. Thus, column 1 shows that the total value of inputs to current production in the primary sector in 1968-69 was $A3745.1 m. and that, for example, $A348.9 m. of this was accounted for by purchases from the general manufacturing sector and $A403.0 m. by purchases of labour services. Similarly column 11 indicates that the total value of private final consumption was $A16482.7 m. with, for example, consumption purchases from the finance and services sector accounting for $A4675.6 m. of the total. Note that the total value of each industry's sales (the row total for the industry) is just equal to the total value of its current purchases (its column total). The row includes an entry "Increase in Stocks" which accounts for current output not used in the period and the column includes an entry "Gross Operating Surplus" which accounts for the excess of revenue over non-capital costs.[1]

All the commodity flows shown in the input-output table reproduced in Table 3.1 are valued at basic values, that is, at the prices received by the sellers rather than at the prices paid by the users. The margins between basic prices and purchasers' prices are accounted for by trade and transport mark-up and by indirect taxes levied on the flows. In input-output tables employing basic valuation, the value of these margins is shown in the rows of the industries which produce the mark-up services, or in the commodity tax row, and in the column of the purchaser of the associated commodity. The margins

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1. Gross operating surplus thus includes depreciation as well as the net return to capital.

necessary for the delivery of any user's purchases to him are treated exactly as if they were a direct purchase of intermediate inputs from the producer of the margins services. Thus, in Table 3.1 much of the flow shown in the eighth row in (say) the second column represents the value of trade and transport mark-up required in the delivery to the mining sector of all its current inputs.[1] Similarly, the thirteenth row includes the indirect taxes levied on commodity inputs to mining.[2]

The final task to be attempted in part (b) of this subsection is to show how an input-output table like that shown in Table 3.1 can be used to generate the data requirements of the input-output model summarized by equations (3.8), (3.10) and (3.14). The intermediate input coefficients which form the matrix A are computed from the industry columns of the input-output table. These coefficients (together with the $L_{\ell j}$) represent the technology of industries in the input-output model and are, therefore, denominated notionally in physical units of input per physical unit of output. The transition from the value units employed in the input-output accounts is achieved by defining the required physical units as the amounts of each commodity (or primary factor) which could be purchased for \$1 at base-period prices. A_{ij} $(i,j = 1, \ldots, n)$ is given by the ratio of the ij^{th} element of the table (i.e., the value of intermediate inputs from industry i used by industry j) to the sum of the j^{th} column (i.e., the aggregate value of output for the j^{th} industry). Hence, using Table 3.1

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1. The mark-up industry may, of course, also make direct sales to its customers. For example, the transport industry produces taxi rides as well as freight services.

2. Alternatively, this margins data could be presented in separate mark-up and tax matrices, the ij^{th} elements of which would show, respectively, the trade and transport mark-up, and the commodity tax associated with the ij^{th} flow in the basic values matrix. Then addition of the mark-up and tax matrices to the basic values matrix would yield a matrix of flows valued at purchasers' prices. Models with price accounting systems more elaborate than the simple input-output model, ORANI for example, may require margins data in the expanded form. See subsection 3.2(b)(viii) below.

the value for $A_{1,3}$, i.e., the input from the domestic primary sector directly required to produce one unit of output in the food processing sector, is 1580.3/4250.5 = 0.37 .

The primary input coefficients $(L_{\ell j})$ are computed in an exactly analogous way, with the same convention about units. In combining the input-output model with the data base given by Table 3.1, we can treat indirect taxes, sales by final buyers, non-competing imports and competing imports as well as labour and capital inputs as "primary inputs." Input coefficients for these six categories are obtained by dividing elements of rows 11 - 16 of Table 3.1 by the corresponding industry-column totals. Thus the labour input coefficient for the primary sector (L_{11}) is 403.0/3745.1 = 0.11 . That is, in 1968-69 the production of each dollars-worth of output in the primary sector required a direct input of 0.11 dollars-worth of labour services.

The extension of the input-output model suggested in equation (3.5) requires data which is not immediately computable from Table 3.1. In the table gross fixed capital expenditue (column 13) is disaggregated by capital input but not by investing industry. Column 13 shows the input composition of aggregate investment for the relevant year but not the composition of investment in each investing industry. The coefficients B_{ij} in equation (3.5) entail the latter information. In order to compute these from Table 3.1, the GFCE column of that table would have to be expanded into a matrix with 9 columns, the i^{th} element of the j^{th} column showing the flow of inputs of type i to capital formation in industry j .[1] The required coefficients can then be computed as the

1. Note that the information is not available from ABS sources for the Australian input-output classification. A project to generate such data has been undertaken in the IMPACT project. See Hourigan (1980).

ratios of the elements of the expanded GFCE matrix to the corresponding column sums.

(c) Limitations

Input-output models with structures similar to that discussed above, remain quite commonly used tools of policy analysis. They are often used, at the national level, to estimate the effects of exogenous changes in final demand on employment, industry output levels and gross domestic product. A recent example in the Australian context is included in the investigation of the tourist industry by the Bureau of Industry Economics (Stanford and McCann (1979)). Australian policy literature also contains examples of the use of input-output analysis for tracing the effects of price shocks through the price structure of the economy. (See Klijn (1973), and Haig and Wood (1976).) Attempts to identify "key sectors," especially in less developed developed economies, are another common use of input-output model.[1] Unit increases in final demand are hypothesized for each sector in turn and the implications for variables such as gross industry outputs, employment, gross national product, foreign exchange requirements are computed.

The input-output model has a number of shortcomings from the point of view of these types of application. In this subsection some of the more important limitations are discussed under two headings : the extreme demand orientation of the model and its specification of international trade.[2] In both cases the passive role played by relative

1. See, for example, Schultz (1976), and Kuyvenhoven (1976).

2. These limitations are discussed further with respect to recent input-output analyses, and input-output-based models in Dixon and Parmenter (1979).

prices in the input-output model is highlighted as a major limit to the usefulness of the model for policy analysis. The passivity is ensured by the technological assumptions of the model and by the treatment of both the level and the structure of final demand (including exports) as exogenous.

(i) Demand orientation

The input-output model described by equations (3.8), (3.10) and (3.14) is a model in which output, and hence primary factor employment levels, are completely demand determined. Factor prices are exogenous and there are no constraints on factor supplies either at the economy-wide level or on individual industries. In subsection 2.2 it was argued that supply constraints, particularly economy-wide constraints, give rise to important forms of interdependence between industries. The input-output model alone will not be able to capture the implications of these forms of interdependence.

Supply-side constraints are not easily compatible with the technological and final demand assumptions of the input-output model. This is because those assumptions allow neither the input structures of individual industries nor the commodity structure of final demand to respond to changes in relative prices. Consider first the imposition of industry-specific supply constraints. The traditional view of the short run in economics is a characterization of the economy as possessing limited flexibility owing to the presence of fixed factors (capacity) in each industry. Imposing capacity constraints on industries in the input-output model places absolute limits on their production levels. The assumed fixed coefficient technology (cf. equation (3.1)) allows industries no scope to circumvent a shortage of one input by changing the proportions in which inputs are used. The interpretation of the input-output model as a short-run model is viable only for an economy in which all sectors have excess capacity and in which labour of all types is less than fully employed. An industry facing a fixed coefficients production function cannot expand its output in the short run by combining increasing amounts of labour with its fixed capital stock : factor proportions are fixed.

The proportions in which primary factors are used by the economy as a whole depend both on the factor combinations employed within individual industries and also on the industrial composition of the economy. Provided that individual industries use factors in different proportions, an emerging scarcity of one factor, which is mobile between industries, can be overcome by shifting the structure of production in the economy more heavily towards industries which use comparatively low shares of the scarce factor in their input mixes.[1] Thus, the factor intensity of the economy as a whole can be variable even when factor proportions within each industry are fixed. Fixed coefficients technology at the industry level is not, therefore, necessarily incompatible with economy-wide supply-constraints.

The mechanism by which an adjustment in factor proportions would be accomplished in a market economy operates via the structure of prices. The price of the relatively scarce factor would increase, raising the relative prices of commodities the production of which makes intensive use of the scarce factor. Purchasers would then be

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1. As explained above (p. 25) it will be necessary to look beyond direct primary input proportions in order to decide which industries are comparatively labour- or capital-intensive.

induced to use less of the commodities whose relative prices are increasing and to substitute instead commodities whose relative prices are falling. The input-output model, however, can accommodate only parts of this adjustment process. In the model described in equations (3.8), (3.10) and (3.14), primary factor prices are exogenous. If we increase the price of one primary input to reflect increased scarcity then relative output prices, described by equation (3.14), will respond in the way outlined above. Prices of commodities produced by industries which use the scarce factor relatively intensively will rise relative to other prices. The model, however, has no mechanism which allows demand to change in response to the change in relative prices. Technological assumptions preclude substitution between commodities in industries' input structures and the level and commodity composition of final demand is exogenous. The model is, therefore, no more amenable to the inclusion of economy-wide factor constraints than it is to the imposition of industry-specific constraints.

(ii) <u>International trade</u>

Despite the obvious weight of policy restrictions on international trade, exports accounted directly for about 16 per cent of Australian gross domestic product in the late 1970's (ABS, (1980), Table 5). A much greater share of domestic activity is undertaken by industries which are heavily dependent on international trade as exporters, import competitors or suppliers of inputs to these trading sectors. International-trade developments will therefore have important implications for economic activity in a large part of the economy. In section 2.2 (for example) it was argued that the balance of payments constraint constitutes a source of industrial interdependence which is especially important for a small open economy such as that of Australia. An implication of the importance of international trade in the Australian economy is that, in appraising the usefulness of an economic model for the analysis of Australian policy issues, the specification of international trade will be an important consideration.

In the input-output model, exports, together with domestic final demand for domestic output, are exogenous. Imports are most coherently treated as non-competing. That is, the assumption of fixed-input-coefficient technology is applied separately to imports and domestic inputs even if imports are classified in the same industry categories as domestic output. Imports are then computed in a separate equation[1] as

$$M = A_m X + Y_m \quad , \qquad (3.15)$$

where M is a vector of imports, A_m is a matrix of coefficients, $(A_m)_{ij}$, the input of imports of type i required per unit of output of domestic industry j , and Y_m is a vector of final demand for imports. The important point to note about this treatment is that neither side of the trade account is modelled as depending on relative prices. Exports are entirely exogenous and imports depend only on the level of activity in the domestic economy. In consequence, the input-output model alone is of limited usefulness for the analysis of international trade issues in which

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1. To add imports and domestic commodities of the same classification in the same equation, for example to write the market clearing equation for domestic goods as

$$X = A^* X + \bar{Y} - M \quad , \qquad (3.16)$$

where A^* is a matrix of coefficients showing unit requirements of commodities undifferentiated as to source, would imply that they are perfect substitutes, i.e., that they are the same commodity. This leaves a problem as to what determines the shares of imports and domestic supplies in total usage. If import prices differ from the prices of domestic commodities, cost-minimizing users would use either imports only or domestic supplies only.

the response of trade flows to changes in domestic relative to world prices are usually taken to be crucial. The implications of the long-run balance of payments constraint for the economy in the face of an exogenous change in trading conditions (a mining boom or a change in the terms of trade), and the impact on the economy of changes in tariff protection are two such issues which were discussed in subsection 2.2 above.

3.2 ORANI : A Johansen-style, Multisectoral Model

The input-output system remains at the heart of modern inter-industry models. Developments in modelling over the last two decades, however, have greatly extended the theoretical structure of the basic input-output model and have expanded the range of industry interactions which can be accommodated. In particular, prices have been made to play a much more active role. By modelling the behaviour of economic agents as explicitly responsive to changes in relative prices, modern inter-industry models are able to go much further in accounting for the types of indirect interaction between industries which were described in subsection 2.2.

Among the many examples of such models which have been documented in the international literature are the model of Norway developed by Johansen (1960), the work of Taylor and Black (1974), models developed in association with the International Monetary Fund (Armington, 1969 and 1970; Artus and Rhomberg, 1973) and the World Bank (Adelman and Robinson, 1978; Dervis, 1975 and 1980), the Cambridge Growth Project (Barker, et al., 1979), the models developed in Canada by the Economic Council o Canada (McCracken, 1973), and Boadway and Treddenick (1977), and the model of the world economy developed by Leontief et al. (1979). In the Australian context, the work of Evans (1972) is seminal.

ORANI is a model in this tradition. In particular it follows the style of Johansen, an important feature of which concerns the question of how to solve a model with a theoretical structure sufficiently complicated to account for the types of interactions within the economy which we wish to model and with sufficient disaggregation of its industry structure to make it useful for policy questions concerning the industrial structure of the real economy. Johansen's method allows solutions for the much more complex model to be obtained by methods no more computationally demanding than those required in the case of the input-output model.

First review how the input-output model described in sub-section 3.1(a) was solved. Ignoring the equations which compute factor demands, the basic theoretical structure of the commodity-output model was given by equations (3.2) (demand functions for intermediate inputs) and (3.6)(market clearing equations for output). Note that this structure involves only equations which are linear in the variables, in particular input demands are linear functions of output levels. In fact, equations (3.2) and (3.6) form a system of $(n^2 + n)$ simultaneous linear equations in the $(n^2 + 2n)$ variables X_{ij}, X_j and Y_j $(i, j = 1, ..., n)$. The system is solved by first setting n variables (the Y_j) exogenously (via equation (3.4)) and substituting equation (3.2) into equation (3.6) to eliminate the X_{ij}. This leaves a condensed system of n linear equations in only n endogenous variables (the X_j), i.e., in matrix notation, equation (3.7).

The condensed system was then solved for its endogenous variables, as in equation (3.8), by inversion of an $n \times n$ matrix $(I - A)$ and multiplication by the vector $\bar{Y}$.[1] The input-output price model (equation (3.11)) is a similar linear system in which output prices are

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1. Note that having solved for the X_j, values for the eliminated variables (X_{ij}) could easily be obtained by back solution via equation (3.2).

linear functions of input prices. It has n equations and the $(n + m)$ variables, P_j , $(j = 1, \ldots, n)$ and W_ℓ , $(\ell = 1, \ldots, m)$. W_ℓ is set exogenously (equation (3.12)) and the system solved for the P_j by the same matrix methods (equation (3.14)). Using modern computers, matrix manipulations of the type required to solve systems of linear equations are routine and reasonably cheap even for very large systems.

As will be shown in this subsection, extensions to the theoretical structure which are made in a more complex model such as ORANI often require the introduction of non-linearities into the model's equations. In particular, allowing for price-induced substitution possibilities between inputs to production processes and final demand leads to non-linear forms for the relevant demand functions. Producers' input demand equations, for example, become non-linear functions of output levels and the relative prices of inputs rather than simply linear functions of output levels alone as in equations (3.2) and (3.3). The basic theoretical structure of a typical modern inter-industry model is therefore represented as a system of simultaneous non-linear equations rather than a linear system.

Methods for solving large systems of non-linear equations are available but are much more costly and much less flexible than linear solution techniques.[1] Johansen's suggestion, which has been followed in solving the ORANI model, was to avoid the problems of non-linear solution procedures by transforming the equations of the model from their original form which is non-linear in the levels of the variables to a representation

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1. For a more detailed discussion, see Dixon (1979).

in terms of the proportional or percentage changes in the variables which is linear. That is, a typical non-linear equation of the model might be written

$$T = f(U, V) \quad , \tag{3.17}$$

where T, U and V are the levels of variables in the model. T, for example, might be the demand for a commodity by some producer, U his level of output, and V the price of the input relative to an index of all input prices. f denotes an unspecified, non-linear function. Equation (3.17) can be totally differentiated and written in proportional changes as

$$\frac{dT}{T} = \left(\frac{\partial f}{\partial U}\frac{U}{T}\right)\frac{dU}{U} + \left(\frac{\partial f}{\partial V}\frac{V}{T}\right)\frac{dV}{V} \quad , \tag{3.18}$$

in which the proportional change in variable T on the LHS of (3.17) is given as a linear function of proportional changes in the two variables from the RHS. The coefficients of (3.18) are, respectively, the elasticities of T with respect to U and V. Under the Johansen procedure these are evaluated numerically from base-period data and treated as constants.[1]

After transformation to its proportional change version, the model can once again be represented as a system of linear equations and solved by matrix manipulation. ORANI, for example, can be represented as

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1. Note that the proportional change solution is therefore strictly valid only for "small" changes in U and V. For "large" changes approximation errors are to be expected. The question of what is, for practical purposes, "large" and "small" is investigated for the case of the ORANI model in Dixon, Parmenter, Sutton and Vincent (1981). In that volume it is also shown that an approximation-free solution for ORANI can easily be obtained by a small number of successive applications of the linear solution technique.

$$Az = 0 \quad , \tag{3.19}$$

where z is a vector of percentage changes in all the model's variables, and A is a matrix of equation coefficients. For ORANI, as for the input-output model, the number of equations in the model (q, say) is smaller than the number of variables (r, say) which appear in these equations. Before equation (3.19) can be solved therefore $(r - q)$ of the variables must be specified exogenously.[1] Equation (3.19) can then be rewritten as

$$A_1 z_1 + A_2 z_2 = 0 \quad , \tag{3.20}$$

where z_1 is a $(q \times 1)$ vector of percentage changes in the endogenous variables, z_2 is a $[(r - q) \times 1]$ vector of percentage changes in the exogenous variables, A_1 is a $(q \times q)$ matrix consisting of the columns of A corresponding to z_1, and A_2 is a $[q \times (r - q)]$ matrix consisting of the columns of A corresponding to z_2.

Matrix manipulation is then sufficient to give a solution for the percentage changes in the endogenous variables in terms of the percentage changes in the exogenous variables as[2]

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1. As will be shown below, there is considerable choice for the user of ORANI as to which variables are treated as exogenous. This choice allows a great deal of flexibility to the user in specifying different economic environments for experiments with the model.

2. In fact, the number of equations and variables in the basic theoretical form of ORANI (see Dixon, Parmenter, Sutton and Vincent, op. cit., Table 1) is too large to be solved directly in this way. Algebraic methods are therefore used to eliminate variables and condense the system to a more manageable size, just as intermediate input demands were eliminated in solving the input-output model. Solution values for the eliminated variables are then obtained by back-substitution.

$$z_1 = - A_1^{-1} A_2 z_2 \quad . \tag{3.21}$$

The typical ij^{th} element of the matrix $- A_1^{-1} A_2$ is the elasticity of the i^{th} endogenous variable with respect to the j^{th} exogenous variable. For example, among the endogenous variables (z_1) we might include percentage changes in output levels for each of the industries distinguished in the model. The exogenous variables might include percentage changes in the ad valorem tariff rates for imports of each import category distinguished. By making equal changes in the tariff rates (a 25 per cent increase, say) the model can be used to project the effects of an across-the-board tariff change. Equation (3.21) will yield projections of the percentage changes in industry-output levels likely to be generated by a 25 per cent across-the-board increase in all tariff rates.

The remainder of this subsection contains an explanation of the type of relationships between economic variables which constitute the system (3.19) for the case of the ORANI model. The explanation proceeds in two stages. First, in part (a), the basic methods used in building up and implementing the model will be illustrated via the construction of a drastically simplified version of a Johansen-style model. This is called the "stylized Johansen model" and has the same basic structure as ORANI itself. Second, in part (b), some details of the main features of the equations which constitute the full ORANI system will be outlined.

(a) A stylized Johansen model[1]

As compared to the open static input-output model, extended inter-industry models, like that of Johansen and ORANI, have a number of important additions to their theoretical structures. Two of the more fundamental are, first, a more elaborate technological specification based on neoclassical production functions which allow cost-minimizing producers to adjust their input mixes in response to changes in input prices, and, second, a degree of closure in the sense that elements of final demand are explained by variables within the model rather than treated as exogenous. Standard micro-economic theory is employed to provide the additions.

A very simple, stylized version of a model incorporating extensions of this type will now be developed. The aim is to provide a model of a Johansen-style model which can be used to illustrate the basic theoretical form of the more elaborate model, to show how this theoretical structure can be built up from standard micro-economic theory, to show how the data requirements of the model can be supplied by commonly available economic data and finally to demonstrate the basic principles involved in manipulating the model to produce projections of the effects of exogenous changes of interest. For these purposes a comparatively simple model with only a small number of economic agents will suffice. The stylized model describes a hypothetical, closed economy (international trade is ignored) with one final consumer, two industries (each producing only a single commodity) and two primary factors. The equations of the model fall into four distinct categories. These are equations describing the demand for commodities for use in final demand; equations describing

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1. This section draws heavily on material originally prepared by Peter Dixon for use in training courses for the ORANI model. See Dixon (1978).

the demand for commodities and primary factors as inputs to production; pricing rules relating the prices of commodities to production costs; and market clearing constraints for commodities and primary inputs. The contents of each of the categories of the stylized model will be set out in detail.

(i) Final demand for commodities

For the stylized model it is assumed that the only source of final demand is domestic household consumption.[1] Domestic households are assumed to be price takers and to maximize a Cobb-Douglas aggregate utility function

$$U = X_{10}^{\alpha_{10}} X_{20}^{\alpha_{20}} , \tag{3.22}$$

subject to a budget constraint

$$P_1 X_{10} + P_2 X_{20} = Y , \tag{3.23}$$

where X_{i0} $(i = 1, 2)$ is final consumption of commodity i. (Note that the second subscript, 0, is used to denote flows to final demand.) P_i is the price of commodity i; Y is aggregate final expenditure; and the α_{i0} are positive parameters normalized so that $\sum_{i=1}^{2} \alpha_{i0} = 1$.

From these assumptions, standard Lagrangean methods[2] can be used to derive consumers' demand functions for the two commodities which take the form

$$X_{i0} = \alpha_{i0} Y/P_i \quad (i = 1, 2) . \tag{3.24}$$

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1. Government spending, investment and exports are all omitted for simplicity.
2. The derivations used in setting up the stylized model are set out in the Appendix.

According to (3.24) consumers' demand for each commodity is a positive function of aggregate consumers' expenditure and a negative function of the commodity's own price. In fact, under the Cobb-Douglas form assumed for the utility function (3.22), the share of expenditure on each commodity in total consumers' expenditure is constant. In other words, the expenditure elasticity of demand for good i is unity and the own-price elasticity is equal to - 1 (cf. equation (3.24)* on p. 54 below). It is clear from (3.24) that α_{i0} is the share of expenditure on commodity i in total consumers' expenditure. The imposition of the Cobb-Douglas form for the utility function in the stylized model has the result that the estimation of parameters for the consumers' demand functions, even in the levels form, is very simple. The required expenditure shares (α_{i0}) could be computed from data on the pattern of consumers' spending in a single period.

(ii) Producers' demands for inputs

In order to obtain producers' input-demand equations for the stylized model each producer, j , is assumed to be a price taker in all input markets and to choose his input combination to minimize the total costs of producing any output level, i.e.,

$$TC_j = \sum_{i=1}^{4} X_{ij} P_i \qquad (j = 1, 2) , \qquad (3.2$$

subject to the constant-returns-to-scale, Cobb-Douglas production function

$$X_j = A_j \prod_{i=1}^{4} X_{ij}^{\alpha_{ij}} \qquad (j = 1, 2) , \qquad (3.2$$

where X_j is the level of output in industry j , the X_{ij} are the usage of intermediate (i = 1, 2) and primary (i = 3, 4) inputs by industry j, and A_j and the α_{ij} are positive parameters with

$$\sum_i \alpha_{ij} = 1 .$$

The solution to the producers' constrained cost-minimization problem yields[1] the following input demand equations

$$X_{ij} = (Q_{ij} X_j \prod_{t=1}^{4} P_t^{\alpha_{tj}}) / P_i \qquad (i = 1, \ldots, 4 ;\; j = 1, 2) , \tag{3.27}$$

where Q_{ij} is a positive parameter given by

$$Q_{ij} = \alpha_{ij} (\prod_{t=1}^{4} (\alpha_{tj})^{-\alpha_{tj}}) / A_j , \tag{3.28}$$

It can be shown[2] that the α_{ij} are the shares of the inputs i in the total costs of industry j; that is,

$$\alpha_{ij} = P_i X_{ij} / \sum_{t=1}^{4} P_t X_{tj} \qquad (i = 1, \ldots, 4 ;\; j = 1, 2) . \tag{3.29}$$

According to equation (3.27), the typical cost minimizing producer in the stylized model, who faces Cobb-Douglas technology (equations (3.26)) will increase his demand for all inputs when his output level increases, and will substitute other inputs for any input i whose price increases relative to a cost-share weighted index $(\prod_{t=1}^{4} P_t^{\alpha_{tj}})$ of all input prices. Just as assumptions about the utility function simplified parameter estimation in the case of the final demand equations, the assumption of Cobb-Douglas technology simplifies the estimation of parameters for the input demand functions. In the Cobb-Douglas

1. See Appendix.

2. See Appendix.

case the elasticity of substitution between any pair of inputs is unity.[1] The cost shares (α_{ij}) could be computed from a single period's data on industry costs. A_j is an arbitrary scale parameter.

(iii) Costs and prices

Commodity-pricing equations for the stylized model can be obtained by making the perfectly competitive assumption that no pure profits are earned, that is, that total revenue is just equal to the total costs of produced and primary inputs, including a rental price for the producer's capital equal to its opportunity cost. Using the notation already defined the assumption is

$$P_j X_j = \sum_{i=1}^{4} P_i X_{ij} \qquad (j = 1, 2) . \tag{3.30}$$

The LHS of equation (3.30) is total revenue for industry j and the RHS is its total costs. Input quantities can be eliminated from equation (3.30) using the input demand equations (3.27). Since constant returns to scale have been assumed via (3.26), the same substitution also eliminates the output level (X_j) and yields unit price equations which express output prices as functions of input prices alone,[2] that is

$$P_j = Q_j \prod_{t=1}^{4} P_t^{\alpha_{tj}} \qquad (j = 1, 2) , \tag{3.31}$$

where

$$Q_j \equiv \sum_{i=1}^{4} Q_{ij} .$$

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1. See equation (3.27)*, p.54

2. See Appendix.

Notice that in equation (3.31) input shares in industries' total costs (the α's) determine the responses of product prices to changes in input prices. The elasticity of output price i with respect to input price j is in fact just α_{ji}, the share j in total costs of i.[1]

(iv) Market clearing equations

The final element of the stylized model is a set of market clearing equations for commodities and primary factors. These are

$$X_i = \sum_{j=0}^{2} X_{ij} \qquad (i = 1, 2\text{: commodities}) , \tag{3.32}$$

and

$$X_i = \sum_{j=1}^{2} X_{ij} \qquad (i = 3, 4\text{: primary factors}) , \tag{3.33}$$

where the X_i for $i = 3, 4$ are the aggregate employment levels of the primary factors. The RHS of equations (3.32) and (3.33) just sum the various categories of demand. Commodities produced by the domestic industries can be used in final demand $(j = 0)$ or as inputs to production $(j = 1, 2)$. Primary factors are used only as production inputs.

One last equation could be added. That is the national income accounting identity equating the aggregate expenditure and aggregate income measures of the gross national product. For the stylized model this is

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1. Cf. equation $(3.31)^*$, p. 54.

$$Y = \sum_{i=3}^{4} P_i X_i \quad . \tag{3.34}$$

Y is aggregate final expenditure as before and the RHS of (3.34) is aggregate primary-factor income for the stylized model. However, it is not difficult to show[1] that equation (3.34) is already implied by the rest of the system and is therefore redundant.[2] On the other hand, the model as it stands will yield a solution only for relative prices. There is no equation to determine the absolute price level. Such an equation can be added simply by choosing any one of the four prices as the numeraire. One such choice is

$$P_1 = 1 \quad . \tag{3.35}$$

Equations (3.24), (3.27), (3.31), (3.32), (3.33) and (3.35) form the basic theoretical structure for the stylized model written in the levels of the variables. This type of model is often referred to as a (computable) general equilibrium model. That is, the model is solved for simultaneous "equilibrium" values of its endogenous variables. It should be noted, however, that the model is not completely closed. There are only 17 equations but 19 variables, X_{i0} $(i = 1, 2)$, Y, P_i $(i = 1, \ldots, 4)$, X_{ij} $(i = 1, \ldots, 4 \; ; \; j = 1, 2)$, and X_j $(j = 1, \ldots, 4)$. In order to close the system, that is, to equate the number of equations in the system to the number of variables to be determined by it, it is necessary to treat two of the variables as exogenous. The type of equilibrium condition imposed in solving the model depends on the choice of exogenous variables. In particular, it is not

1. See Appendix.

2. Note that this represents the application of Walras' Law to the model.

necessarily true that all markets must clear in the usual sense. For example, employment levels for both primary factors could be specified, i.e., X_3 and X_4 set exogenously. The model could then be used to solve for values of the remaining 17 variables, including the values of the primary factor prices (P_3 and p_4) necessary to clear the factor markets. Alternatively, however, the price of one factor could be set exogenously leaving the model to determine its employment level. If, for example, primary factor 3 is defined as labour, primary factor 4 as capital, and P_3 and X_4 are set exogenously, the model becomes one with a fixed endowment of capital but a labour supply which is perfectly elastic at the given wage rate. In the second case it is clear that the model is not a full general equilibrium system with respect to the labour market. Even in the first case there is no reason why the exogenously set employment level need correspond to full employment.

Both of the closures outlined in the previous paragraph are legitimate possibilities. There are, however, restrictions on which variables can legitimately be set as exogenous. For example, suppose that we set the two factor prices (P_3 and P_4) exogenously, recalling that one commodity price (P_1) has already been set as the numeraire via equation (3.35). This leads to two problems. In the first place the model's price system might be inconsistent. There are two price equations (3.31) but only one endogenous price (P_2). If we are lucky enough to find a value for P_2 which satisfies both equations in (3.31) we are left with the second problem. Delete equations (3.31) and (3.35) and all four prices from the model and 14 equations remain to determine 15 variables, all quantities rather than prices. The selection of P_3 and P_4 as exogenous is illegitimate because then there is no exogenous quantity variable to determine the absolute size of the economy. The model will therefore yield a solution only for relative quantities just as, without a numeraire, only relative prices could be derived.

The opportunity to choose different sets of exogenous variables, that is to impose different equilibrium conditions or economic environments on the model, gives the user an important element of flexibility in his uses of the model. For the case of ORANI a large number of possible choices is available. Some of the most useful are discussed in sub-section 4.1.

Pursuit of the Johansen method for solving the stylized model requires that its equations be converted to their percentage change form. The transformed equations are given below.[1] The same numerical identifiers are used as were used for the corresponding levels versions but an asterisk has been added to denote the transformation. Lower case letters are used to denote the percentage changes of equivalent level variables (e.g., $x_i/100 = dX/X$)

$$x_{i0} = y - p_i \qquad (i = 1, 2) , \tag{3.24}^*$$

$$x_{ij} = x_j - (p_i - \sum_{t=1}^{4} \alpha_{tj}\, p_t) \qquad (i = 1, \ldots, 4 ; \; j = 1, 2) , \tag{3.27}^*$$

$$p_j = \sum_{t=1}^{4} \alpha_{tj}\, p_t \qquad (j = 1, 2) , \tag{3.31}^*$$

$$x_i = \sum_{j=0}^{2} B_{ij}\, x_{ij} \qquad (i = 1, 2) , \tag{3.32}^*$$

$$x_i = \sum_{j=1}^{2} B_{ij}\, x_{ij} \qquad (i = 3, 4) , \tag{3.33}^*$$

$$p_i = 0 , \tag{3.35}^*$$

where

$$B_{ij} = X_{ij}/X_i \qquad (i = 1, \ldots, 4 ; \; j = 0, 1, 2) .$$

1. See Appendix for transformation rules.

That is, B_{ij} is the share of total sales of commodity i $(i = 1,2)$ or primary factor i $(i = 3,4)$ which is accounted for by sales to industry j $(j = 1,2)$ or to final demand $(j = 0)$. Note that in its transformed version, the model is linear in the percentage change variables. The asterisked equations have been written in the tableau form of the matrix representation (3.19) in Table 3.2 ; that is, the interior of the tableau defines the elements of the matrix A for the stylized model. The first task would be to choose the exogenous variables and to split the A matrix into submatrices A_1 (the columns of A corresponding to the endogenous variables) and A_2 (the columns corresponding to the exogenous variables). For example, for the first of the closures suggested on p. 53 (X_3 and X_4 exogenous), columns 1 - 9 and 12 - 19 of Table 13.2 would form A_1 and columns 10 and 11 would form A_2.. The system could then be solved by the matrix manipulations described by equations (3.20) and (3.21).

An option which might be exercised before application of the solution method is to reduce the size of the system by algebraic substitutions. For example, in the stylized model, the consumer demand variables (x_{i0}) and the input demands (x_{ij}) could easily be eliminated by substituting equations $(3.24)^*$ and $(3.27)^*$ into the remaining equations to give a condensed system of 7 equations in 9 variables as follows :

$$p_j = \sum_{t=1}^{4} \alpha_{tj}\, p_{tj} \,, \qquad (j = 1,\ 2)\,, \tag{3.31*}$$

$$x_i = (y - p_{i0})\, B_{i0} + \sum_{j=1}^{2} (x_j - (p_i - \sum_{t=1}^{4} \alpha_{tj}\, p_t))\, B_{ij} \qquad (i = 1,\ 2)\,, \tag{3.32**}$$

$$x_i = \sum_{j=1}^{2} (x_j - (p_i \sum_{t=1}^{4} \alpha_{tj}\, p_t))\, B_{ij} \,, \qquad (i = 3,\ 4)\,, \tag{3.33**}$$

$$p_i = 0 \,. \tag{3.35*}$$

Table 3.2 : Tableau representation of the linear, stylized Johansen model

Variable / Equation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	x_{10}	x_{20}	y	p_1	p_2	p_3	p_4	x_1	x_2	x_3	x_4	x_{11}	x_{12}	x_{21}	x_{22}	x_{31}	x_{32}	x_{41}	x_{42}
$(3.24)^*$ .1	1		-1	1															
$(3.24)^*$ .2		1	-1		1														
$(3.27)^*$ .1				$(1-\alpha_{11})$	$-\alpha_{21}$	$-\alpha_{31}$	$-\alpha_{41}$	-1				1							
$(3.27)^*$ .2				$(1-\alpha_{12})$	$-\alpha_{22}$	$-\alpha_{32}$	$-\alpha_{42}$		-1				1						
$(3.27)^*$ .3				$-\alpha_{11}$	$(1-\alpha_{21})$	$-\alpha_{31}$	$-\alpha_{41}$	-1						1					
$(3.27)^*$ .4				$-\alpha_{12}$	$(1-\alpha_{22})$	$-\alpha_{32}$	$-\alpha_{42}$		-1						1				
$(3.27)^*$ .5				$-\alpha_{11}$	$-\alpha_{21}$	$(1-\alpha_{31})$	$-\alpha_{41}$	-1								1			
$(3.27)^*$ .6				$-\alpha_{12}$	$-\alpha_{22}$	$(1-\alpha_{32})$	$-\alpha_{42}$		-1								1		
$(3.27)^*$ .7				$-\alpha_{11}$	$-\alpha_{21}$	$-\alpha_{31}$	$(1-\alpha_{41})$	-1										1	
$(3.27)^*$ .8				$-\alpha_{12}$	$-\alpha_{22}$	$-\alpha_{32}$	$(1-\alpha_{42})$		-1										1
$(3.31)^*$ .1				$(1-\alpha_{11})$	$-\alpha_{21}$	$-\alpha_{31}$	$-\alpha_{41}$												
$(3.31)^*$ .2				$-\alpha_{12}$	$(1-\alpha_{22})$	$-\alpha_{32}$	$-\alpha_{42}$												
$(3.32)^*$ .1	$-B_{10}$							1				$-B_{11}$	$-B_{12}$						
$(3.32)^*$ .2		$-B_{20}$							1					$-B_{21}$	$-B_{22}$				
$(3.33)^*$ .1										1						$-B_{31}$	$-B_{32}$		
$(3.33)^*$ .2											1							$-B_{41}$	$-B_{42}$
$(3.35)^*$				1															

$= 0.$

The advantage of the condensation procedure is that it reduces the size of the system which must be handled at the computing stage. In the example given it has reduced the size of the matrix A_1 which is to be inverted (see equation (3.21)) from (17×17) to (7×7). Inversion of the (17×17) matrix of the uncondensed version of the stylized model would not be a major computing task, but for larger systems such condensation might be very valuable.[1] The costs of condensation, apart from the algebra required, are that eliminated variables cannot easily be made exogenous and that if solution values for them are required these must be obtained by back solution following the computation of any solution to the condensed model. The values of the x_{i0} in the stylized model, for example, could be obtained by substituting into equation $(3.24)^*$ the solution values of y and the p_i obtained from the condensed system.

The final point to be made about the stylized model concerns its data requirements. The explicit parameters of the model represented by equations $(3.24)^*$, $(3.27)^*$, $(3.31)^*$, $(3.32)^*$, $(3.33)^*$ and $(3.35)^*$ are of two types : industry cost shares (the α_{ij}) and user sales shares (the B_{ij}) for both commodities and primary factors. Note, however, that other data have implicitly been supplied to the model as theoretical assumptions, especially in the utility and production functions. Expenditure elasticities of consumer demand and the elasticities of substitution between inputs to production have all been set to unity and own price elasticities of consumer demand set to - 1 as consequences of the functional forms chosen for utility and production functions. In a more realistic model, less restrictive assumptions might be imposed so that various para-

1. The ORANI theoretical structure, for example, contains approximately 5 million equations (see Dixon, Parmenter, Sutton and Vincent, Table 23.1). It is condensed to about 300 equations before computation.

meters such as the consumer and substitution elasticities would be required from econometric evidence. In currently implemented versions of ORANI, for example, CES rather than Cobb-Douglas production technology is imposed. Theoretical assumptions still play an important role in limiting the data requirements to manageable proportions.

For the case of the stylized model, all the parameters which need to be supplied from data about the economy to which the model is to be applied can readily be obtained from input-output tables. Refer back to Table 3.1 and note that that table describes an economy which is more elaborate than the economy implicit in the stylized model. In particular, Table 3.1 distinguishes more industries and final demand categories and includes international trade flows. With those qualifications it should be apparent that cost shares such as the α_{ij} are just shares in the column total of individual entries in an industry column in the input-output table. Industry sales shares such as the B_{ij} for $i = 1,2$, in the stylized model are the shares in the row total of the entries along an industry row. The primary factor sales shares are, similarly, the shares in the relevant row total of the entries along a primary factor row in the table. For example, in the economy represented by Table 3.1, the share of inputs from industry 2 in the total costs of industry 5 (i.e., $\alpha_{2,5}$ following the notation of this section) is $459.7/12601.1 = 0.036$. Similarly, the share in the total sales of industry 2 which is accounted for by sales of intermediate inputs to industry 5 (i.e., $B_{2,5}$) is $459.7/1149.1 = 0.400$. Finally, the share of total payments to labour accounted for by employment in industry 8 is $3442.3/14029.5 = 0.245$.

(b) Some details of the ORANI structure

The stylized model described in the previous subsection is a convenient, simplified caricature of ORANI. It served to introduce the general classes of equations which comprise the ORANI structure (final demand equations, equations describing producers' demands for inputs, pricing equations and market clearing constraints), to demonstrate how these can be derived from orthodox propositions of microeconomic theory (constrained optimization by producers and consumers, competitive assumptions, etc.), to illustrate the linearization method proposed by Johansen and to show how the parameters of the linearized model can be constructed from commonly available economic data. ORANI itself has been constructed, linearized, implemented empirically and solved in a manner exactly analagous to that outlined for the stylized model. ORANI is, however, a much more elaborate model in terms of the number of sectors distinguished, the degree of detail in which final demand and primary inputs are modelled, the assumptions made about technology, and the price structure of the model. In this subsection some details are given of the way in which these issues are handled in ORANI. The aim is to give a general account of the economics underlying the ORANI structure. Full technical details are given in Dixon, Parmenter, Sutton and Vincent (1981).

(i) Industry and labour-force classification

The core of the data base for ORANI is the input-output tables compiled by the Australian Bureau of Statistics (ABS, 1977). The first publicly documented version of ORANI (Dixon, Parmenter, Ryland and Sutton, 1977) used precisely the same industrial classification as that chosen for the input-output tables. The model thus distinguished 109, ASIC-based industries. For the more recent version of the model some modifications have been made to the industrial classification (Dixon, Parmenter, Powell and Vincent, 1979). The main change is in the agricultural sector where, instead of the six, single product input-output groupings, ORANI distinguishes eight industries, four of which produce more than one commodity. Ten agricultural commodities are distinguished. They are wool, sheep meat, wheat, barley, other cereal grains, meat cattle, milk cattle and pigs, other farming export, other farming import competing, and poultry. The revision of the agricultural data was made to accommodate an explicit modelling of the multi-product nature of most Australian farms. For non-agricultural sectors the input-output convention of single-product industries is retained. The complete industry classification is given in the table of industry results in subsection 4.2(b), i.e., Table 4.2.

Labour input in ORANI is disaggregated into nine broad occupational categories. A matrix of labour input by occupation and industry was compiled, consistent with the labour input data in the input-output tables, on the basis of population-census data. The ORANI labour-force categories are listed in Table 4.1 in the results section.

(ii) International trade

One major contrast between ORANI and the stylized model is that ORANI is a model of an open economy. Particular attention has been paid to the specification of international trade, both because of the importance of trade to the Australian economy generally and because the model was designed partly for use in formulating advice on trade policy within relevant government departments.

Australia is assumed, in ORANI, to be a small buyer in the markets for its imports. World prices for imports are, therefore, independent of the level of Australian demand for imports. In the domestic market, imports are assumed to compete with domestic output of the same commodity classification but not to be perfect substitutes. That is, the shares of imports and domestic supplies in each domestic user's total purchases of any importable commodity are assumed to depend on the relative prices of supplies from the two sources.[1] The model contains demand functions for commodities identified by commodity category and source of the following form[2]

$$x_{isj} = \psi_{ij} - \sigma_i (p_{isj} - \sum_{t=1}^{2} S_{itj}\, p_{itj}) \quad , \tag{3.36}$$

where x_{isj} is the percentage change in the demand for commodity i, from source s ($s = 1$ indicates that the commodity is domestically produced and $s = 2$ that it is imported), by user j (j can identify an industry if the commodity is to be used as an input to current production or capital formation, or it can identify the final demand category, household consumption). ψ_{ij} is an activity variable which defines the percentage change in user j's demand for commodity i in general (i.e., for "effective" units of commodity i not distinguished by source; see footnote 2). p_{isj} is the percentage change in the

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1. An exception is the treatment of government current expenditure which is assumed exogenous with regard to its commodity and source compositions.

2. This form follows from assuming that domestic users of any good i choose their combinations of imports and domestic supplies of the commodity so as to minimize the total cost of their requirements of "effective" units of i subject to the definition of an effective unit of i as a CES combination of imports and domestic supplies.

price paid by user j for commodity i from source s . σ_i is the elasticity of substitution between imported and domestically produced supplies of commodity i and S_{itj} is the base-period share of source t in user j's total purchases of commodity i .[1] Equation (3.36) says that, for any given level of demand for good i in general, an increase in the price of imports (say) of good i relative to a share weighted average of the imported and domestic prices (the percentage change in this average is the second term in the brackets on the RHS of (3.36)) will lead to a reduction in the demand for imports and an increase in the demand for domestically produced good i .

Key parameters necessary for the empirical implementation of these assumptions are the elasticities of substitution (σ_i) between imports and domestic sources of commodities, that is, the parameters which describe the percentage change in the import-domestic shares of the usage of each commodity likely to result from a one per cent change in the relevant import/domestic price ratio. A major econometric effort has been mounted to provide estimates of these parameters for the Australian economy at the level of commodity disaggregation employed by ORANI. Results, methods and data are described in Alaouze (1976 and 1977), Alaouze, Marsden and Zeitsch (1977) and Marsden and Milkovits (1977). The results indicate that at the relevant level of disaggregation, a typical value for the elasticity of substitution between imports and domestic output is about two. Higher values were obtained for some of the major import categories (e.g., 3.4 for clothing, 6.8 for footwear and 5.0 for motor vehicles and parts) and much lower values (about 0.5) were assumed for most of the capital goods.

1. These shares can easily be computed on the basis of comparisons between input-output data with direct and indirect allocation of imports. See p. 30, especially footnote 2.

Exports from Australia's major export industries are assumed, in ORANI, to be sensitive to both domestic cost conditions and overseas demand. World prices of exports are not assumed to be independent of Australian supplies to the world markets although the relevant foreign demand elasticities are typically high.[1] Subject to the postulated foreign demand curves, the major exporters are assumed to determine export volumes on conventional profitability criteria. Domestic sellers' prices of the major export commodities are therefore closely tied to their world prices. In the standard version of ORANI exports are determined in this way for the following commodities : wool, wheat, barley, other grains, fishing, iron, other metallic minerals, coal, meat products, food products n.e.c. (mainly sugar), prepared fibres, basic iron and steel, and other basic metals. For all other exported commodities, exports are exogenous and domestic prices fixed by domestic cost and demand conditions unconstrained by world prices.

To complete the specification of international trade in the theoretical structure of ORANI, an equation is included which defines the balance of trade as the difference between the aggregate foreign-currency value of exports and the foreign-currency cost of imports. In model simulations, the balance of trade can either be left to be determined by the model or set as an exogenous constraint on the solution.

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1. Best estimates of these elasticities for the major export commodities are given in Freebairn (1978). The values used in the current version of ORANI range from 1.3 (wool) to 20 (minerals, sugar and non-wheat grains).

(iii) Aggregate domestic final demand

The treatment of exports is an example of the endogenization in ORANI of elements of final demand, in this case foreigners' demand for Australian products. Three other categories of final demand are distinguished in the model : consumption by domestic households, investment and current government spending. Together, these three constitute aggregate domestic absorption. Just as in the case for the stylized model, ORANI is constrained by an (implicit) national income identity [1] which may be written as

$$GDP = A + (E - M) , \qquad (3.37)$$

where GDP is the real gross domestic product, A is real domestic absorption, E is real exports and M is real imports. Unlike the short-run Keynesian model or the open-static input-output model, aggregate demand (the RHS of equation (3.37)) is not usually of overriding importance in determining the GDP. GDP can be regarded as largely determined by the constraints imposed on the supply side of the model. [2] The current version of ORANI contains no equations which explicitly relate domestic

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1. Recall that this was the equation eliminated by Walras' law from the stylized model.

2. For example, consider a typical short-run simulation from ORANI in which technology and industries' capital stocks are fixed and labour supply is assumed to be perfectly elastic at a fixed real wage. In a one-sector model with a neo-classical production function and competitive, profit-maximizing producers, these assumptions would be enough to fix employment : employment is determined at the level at which the real wage equals the marginal product of labour which is known for each level of employment With both employment and the capital stock thus fixed, output is fixed. All that remains is to determine the allocation of GDP between domestic absorption and the balance of trade. ORANI, of course, is a multi-sectoral model whose sectors differ in capital intensity. Compositional effects, therefore, can produce output responses to demand changes even with fixed real wage rates and neo-classical short-run assumptions.

absorption to elements of national income (a Keynesian consumption function for example). If a balance of trade constraint is imposed on the model (i.e., if (E - M) is fixed) it is natural to determine absorption endogenously. Alternatively, real absorption can be fixed exogenously and the model can determine the appropriate value for the balance of trade.

(iv) Household consumption

Even when the levels of the domestic national expenditure aggregates are exogenous, the commodity composition of both household consumption and domestic investment is explained in the ORANI theory. The determination of consumption proceeds along similar lines to those followed for the stylized model. Consumers are assumed to behave as if they maximize an aggregate utility function subject to an aggregate budget constraint. Utility is defined as a function of levels of consumption of commodities of each commodity category.

In the open-economy model commodities are distinguished both according to commodity-type and source (imports or domestic). The source composition of households' consumption of each type of commodity is determined by the relative prices of imports and domestic supplies as explained above. [1] Household demand functions for each type of commodity implied by the utility maximization assumption are functions of aggregate expenditure and commodity prices [2] and can be written in percentage change form as

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1. See subsection 3.2(b)(ii). In the application of the source demand equation (3.36) to household demand the activity variables (ψ_{ij}) are the $x_i^{(3)}$ determined by equation (3.38).

2. The price of each type of commodity is defined as a weighted average of the relevant import and domestic prices.

$$x_i^{(3)} = \varepsilon_i \, c + \sum_{j=1}^{g} \eta_{ij} \, p_j^{(3)} , \qquad i = 1, \ldots, g , \tag{3.38}$$

where $x_i^{(3)}$ is the percentage change in the demand for commodity i, c is the percentage change in aggregate consumption, $p_j^{(3)}$ is the percentage change in the price paid by households for commodity j, ε_i is the expenditure elasticity of demand for good i, and η_{ij} is the cross price elasticity of demand for good i with respect to the price of good j.

An extensive literature exists which is concerned with the question of how to estimate the expenditure- and price-elasticity parameters required by (3.38) on the basis of limited information about household expenditure responses to income and price changes.[1] Assumptions about the form of the utility function serve to impose restrictions on the parameters. Recall for example that the Cobb-Douglas form chosen for the stylized model implied that the expenditure elasticity of demand for each good (i.e., ε_i) was equal to one, that own-price elasticities (i.e., η_{ij} for $i = j$) were equal to minus one and that all cross-price elasticities (i.e., η_{ij} for $i \neq j$) were equal to zero. The consumption parameters used in the currently implemented version of ORANI were generated from less restrictive assumptions.[2] Expenditure elasticities can deviate from unity and hence ORANI is able to account for the empirical observation that, as income increases, the shares of some items in total spending (personal services or

1. See Barten (1977).

2. The utility functions was assumed to be of the form suggested by Klein and Rubin (1948-49) which yields the linear expenditure system as the framework for estimation. On the basis of this, parameters were estimated at the 15 commodity level. The resulting estimates were then mapped into the ORANI commodity classification. See Tulpulé and Powell (1978).

consumer durables, for example) increase at the expense of the shares of other items (food, for example). Cross-price effects can be non-zero but the range of substitution effects currently allowed is limited by the assumption, implied by the chosen utility function, that the marginal utility of any commodity is independent of the level of consumption of any other commodity. An increase in the price of good j will affect the demand for good i because all commodities "compete for the consumer's dollar"[1] but not because of any specific substitution relationship between the two commodities. Such an assumption is clearly less satisfactory the more commodity disaggregation is recognized in the consumption bundle. The theoretical structure of ORANI can accommodate consumption parameters generated from much more general assumptions about the form of the utility function. The effective constraint on the range of substitution possibilities allowed is the availability of data to support the econometric estimates of the required parameters.

(v) The demand for investment goods

There is nothing in the current version of ORANI to determine the level of aggregate investment in the economy. This is usually determined exogenously by an assumption about the share of investment in aggregate domestic absorption (see subsection 3.2(b)(iii)). However, the allocation of a large proportion of the aggregate investment budget among investing industries is determined in the model by movements in relative rates of return. An increase in an industry's expected rate of return relative to the economy-wide rate will induce that industry to expand its investment and acquire an increased share of the

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1. See Phlips (1974, section 3.1). The offsetting benefit of making this simplification is that the $(g \times g)$ matrix of own- and cross-price can be computed on the basis of g expenditure elasticities and one other estimated parameter. See also Powell (1974).

economy's investment budget. The readiness with which industries expand investment in response to increases in expected rates of return is reflected, in ORANI, by parameters in the industry-investment functions which reflect recent historical experience in the Australian economy. This part of the ORANI investment theory is generally overwritten for a group of industries, mainly public sector industries, for which it is not considered plausible. For these industries, investment is then fixed exogenously.

Once the composition of investment by investing industry is determined, the demand for investment goods follows from the commodity composition of investment in each industry. ORANI contains data which describe this composition for a typical unit of investment in each industry.[1] The technology assumed for combining inputs of each commodity type into capital in each industry is of the Leontief variety. That is, inputs are assumed to be used in fixed proportions with no substitution allowed between, say, steel and plastics in response to changes in their relative prices. The source composition of each (cost miminimizing) investor's usage of any input is, however, modelled as a function of the relative prices of imports and domestic supplies in the usual way. (See section 3.2(b)(ii) above.) In applying equation (3.36) to the demand for investment goods the activity variables (ψ_{ij}) are equal to the percentage changes (y_j) in industries' investment levels, i.e.,

$$\psi_{ij} = y_j \quad , \text{ for all } i \, . \tag{3.39}$$

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1. That is, the investment vectors from the input-output tables have been disaggregated into investment matrices which show inputs to investment disaggregated by industry of use as well as by type of input (cf. pp. 33-4 above).

Equation (3.39) follows from the Leontief assumption which implies that for cost minimizing investors the demand for each commodity distinguished only by commodity type, not source,[1] will be proportional to the level of investment.

In summary, then, the demand for inputs to capital formation depends, in ORANI, on aggregate investment, movements in relative rates of return between industries and the prices of domestically produced investment goods relative to imports.

(vi) The demand for inputs to current production

In the stylized model presented earlier both primary and produced inputs were assumed to enter into industries' production functions in the same way (see equation (3.26)). The producers' cost minimization problem yielded input demands as functions of output levels and all input prices (see equation $(3.27)^*$). Substitution was allowed between all types of inputs although all pairwise elasticities of substitution were restricted to unity. The production specification employed in ORANI allows a restricted range of substitution possibilities between inputs but, where substitution is allowed, the relevant substitution parameters are not so severely constrained by the theory.

Producers' demand functions for current, produced inputs in ORANI are strictly analogous to demands for investment goods described in the previous subsection. The assumed production functions require intermediate inputs of each commodity type in fixed proportions, i.e., no

1. That is, demand for "effective units" of each commodity (see footnote 2 on p. 61).

substitution possibilities are allowed between alternative produced-input categories. Once again, however, substitution between imports and domestic supplies of the same commodity category is allowed and producers select their input sources so as to minimize input costs. Equation (3.36) can therefore readily be applied to represent demands for current inputs. The x_{isj} must now be interpreted as demands for intermediate inputs, the s_{itj} as source shares in intermediate usage of commodities and the activity variable (ψ_{ij}) is equal, for all i, to the current output level of industry j .

Allowing for substitution in response to relative price changes between different types of intermediate inputs would involve no serious theoretical complications in ORANI although it would expand the size of the model. The main reason for ruling out such substitution possibilities is empirical. In the first place the time-series input-output data which would be required to estimate the relevant substitution parameters are simply not available for Australia. Secondly, to the extent that the issue has been investigated with more extensive data bases overseas, there is no strong evidence of reliable relationships between input-output coefficients and relative prices (Sevaldson, 1976).

Demand functions for primary inputs in ORANI reflect neo-classical, value-added production functions which are assumed in the model. No substitution is allowed between produced and primary inputs. The real cost of the former can simply be deducted from the real value of output and producers can be regarded as combining primary inputs to produce net output or value added. A CES form is specified for these latter production functions in currently implemented versions of ORANI. Cost minimizing producers will then operate on primary-input demand functions of the form (in percentage changes)

$$\ell_{ij} = z_j - \sigma_j^p (w_i - \sum_{k=1}^{L} s_{kj} w_k) \quad , \qquad (3.40)$$

where ℓ_{ij} is the demand for the i^{th} primary input by the j^{th} industry, z_j is the output of the j^{th} industry, w_k is the price of the k^{th} primary input, s_{kj} is the share of the k^{th} input in total primary costs of industry j, σ_j^p is the elasticity of substitution between primary inputs in the j^{th} industry, and L is the number of primary factors.

The s_{kj} can easily be computed from input-output data. For example, in Table 3.1, where primary inputs are represented by rows 11 and 12, the share of labour in the total primary costs of industry 2 is 319.8/(319.8 + 344.4) = 0.48. Obtaining empirical estimates of the elasticity of substitution parameters (σ_j^p) is notoriously difficult. The values used in the current version of ORANI were selected on the basis of a thorough survey of the available econometric evidence by Caddy (1976).

Demand functions of the form of (3.40) were derived in ORANI for three categories of primary inputs : labour, fixed capital and agricultural land. Labour is not, however, homogeneous in ORANI. Nine occupational categories are distinguished and provision is made in the ORANI theory for substitution between labour categories in response to changes in relative wage rates.[1] Because reliable estimates of the required labour-labour substitution parameters were not available, most

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1. CRESH or CES aggregation functions for labour are specified. For the purposes of equation (3.40) the required aggregate price of labour is a share weighted average of the occupation-specific wage rates.

ORANI experiments have been conducted under the assumption of fixed wage relativities, thus effectively bypassing the model's labour force substitution provisions.

To summarize, the ORANI input-demand functions reflect a technological specification which allows substitution between imports and domestic supplies of the same type of produced inputs but not between alternative categories of produced input; which allows substitution between labour, capital and agricultural land but not between primary inputs and produced inputs; and which, finally, allows substitution between occupations in the formation of an industry's aggregate input of labour.

(vii) Industry-outputs : the agricultural sector

As was the case for both the input-output and the stylized Johansen models which were discussed earlier, there is in ORANI a one-to-one correspondence between industries and commodities for most sectors. That is, most industries produce only one commodity, and most commodities are produced in only one industry. It was, however, necessary to abandon that convention for the modelling of agriculture. Multi-product enterprises are basic to Australian agriculture and their major inputs are better regarded as general rather than product specific. Under the characterization of agriculture adopted in ORANI, agricultural commodities can be produced by a number of agricultural industries. The typical agricultural industry combines inputs (land, labour, capital, fertilizers, etc.) to produce a bundle of agricultural commodities. The amount of inputs used defines a generalized capacity to produce [1] but the commodity

1. That is, it defines the position of the industry's production possibility curve.

composition of production can be varied without changes to the input bundle. Within these agricultural industries producers select their output mixes so as to maximize revenue subject to empirically specified production-possibility frontiers.[1] This yields commodity supply equations of the following form (in percentage changes)

$$x_{ij}^{(0)} = z_j + \phi_{ij} (p_i - \sum_r p_r S_{rj}^*) , \tag{3.41}$$

where $x_{ij}^{(0)}$ is the percentage change in the production of commodity i by industry j, z_j is an index of the level of activity in industry j, p_i is the producers' price of commodity i, the S_{rj}^* are a weighting scheme for aggregating commodity prices into an industry average price for industry j, and ϕ_{ij} is a (positive) parameter reflecting the ease with which commodity i can be substituted for other commodities in the product mix of industry j.

Under the supply system (3.41), if the price of an agricultural commodity, i, which is part of the production bundle of industry j, increases relative to a weighted average of the prices of all commodities produced in that industry[2] then industry j will increase the share of commodity i in its production bundle. For example, wool and wheat are the main commodities produced by the Wheat-Sheep Zone (industry 2 in ORANI). An increase in wool prices relative to wheat prices will cause wheat-sheep-zone farmers in the model to produce more wool and less wheat at any given overall level of output (z_j).

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1. A CRETH specification was chosen and a major econometric effort was mounted to estimate the required product-transformation parameters. See Vincent, Dixon and Powell (1980).

2. The percentage change in this average price is given by the second term in brackets on the RHS of equation (3.41).

(viii) Price accounting

In the stylized Johansen model only a single price was distinguished for each commodity. It is clear however, even from the brief description given here, that in some parts of the ORANI theory, input and final demand equations for example, it is the prices paid by users (i.e., purchasers' prices) which are relevant whilst for other parts of the theory, producers' output decisions in particular, it is prices received by the producers (i.e., basic value prices) that should enter the behavioural equations.

The producer- and user-price of a commodity are not generally identical. The price paid by the user typically includes a margin over the producer-price which covers the costs of trade and transport services incurred in the delivery of the commodity from the producer to the user. The margin will also include the value of any commodity tax payable or subsidy receivable on the transaction. Moreover, the size of the margin on a given commodity will often vary across users. Sales taxes and retail mark-ups, for example, are often incurred on sales to final consumption but not on intermediate sales of the same commodity.

ORANI contains a detailed price-accounting system which models explicitly the structure of purchasers' prices. The structure allows the prices paid for the same commodity to differ between users. Schematically, the model contains accounting equations of the following form (in percentage changes)

$$p_{isj} = p_{is} S^{BV}_{isj} + \sum_m p_m S^m_{isj} + t_{isj} S^T_{isj} , \qquad (3.42)$$

where p_{isj} is the percentage change in the price of commodity i from source s, to user j, p_{is} is the percentage change in the basic-value price of good i from source s, p_m is the percentage change in the price of margins service m, t_{isj} is the percentage change in the commodity tax per unit sale of good i from source s to user j, and S^{BV}_{isj}, S^{m}_{isj} and S^{T}_{isj} are, in turn, the shares of the basic value, the cost of the m^{th} mark-up service and commodity taxes in the price of good i, from source s to user j.[1] Data for the construction of the necessary price shares were obtained from the margins matrices[2] and commodity tax matrices compiled as part of the preparation of the input-output tables.

Note that, in equation (3.42), neither the basic value price (p_{is}) nor the price of margins services (p_m) differ across users. The shares (the S's) do however carry a j subscript reflecting the possibility that the amount of margins (or taxes) required for delivery of commodity i to its users may differ among users. In addition commodity tax rates also are user specific.

Apart from the explicit modelling of the relationship between producers' and purchasers' prices, price formation in ORANI is strictly analagous to price determination in the stylized Johansen model.[3] Zero-pure-profits constraints are imposed on domestic producers. Since producers are assumed to be price takers and since ORANI's production functions exhibit constant returns to scale, neither revenue nor costs per

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1. Basic value prices of imports are defined as their landed, duty-paid prices and purchasers' prices of exports as their f.o.b. prices at port of exit.

2. The typical ij^{th} cell of the m^{th} margins matrix shows the value of the m^{th} margins service associated with the transfer (shown in the main input-output table) of commodity i to user j.

3. See subsection 3.2(a)(iii).

unit output depend on the scale of output. Just as in the case of the stylized model, basic value output prices depend only on the prices of inputs to production, including the rental prices on the industries' capital. In the case of produced inputs it is the purchasers' prices to producers which are relevant.

Before leaving the pricing structure of ORANI it should be noted that capital formation, importing and exporting are activities represented in ORANI which are ignored in the stylized model. Zero-pure-profits conditions are also imposed on these activities. The cost of a unit of capital to industry j can then be defined as depending only on the prices of inputs to capital formation in that industry; the at port, duty paid price of an import depends only on its foreign currency price, the exchange rate and the tariff rate; and the f.o.b. export price depends only on the foreign currency price, the exchange rate and the export tax rate. Similarly equation (3.42) can be regarded as imposing a zero-pure-profits constraint on the distribution of commodities from producers (or entry ports) to users (or exit ports). The distribution activity is the final activity modelled in ORANI.

(ix) Market clearing equations

Market clearing equations in ORANI have exactly the same form as those of the stylized model but ORANI's market clearing structure must reflect the greater level of detail of the full model. Separate market clearing equations are included for imports and domestic commodities. Although commodities from both sources are classified in the same commodity classification, imports of a given category are distinct from domestic supplies because they are not assumed to be perfect substitutes. The RHS of the market clearing equation for each source-specific good must account for demands for that good as an input to domestic production, as an input to capital formation, as a margins service, as an input to household and government consumption, and as an export.

Turning from commodities to primary factors, ORANI's market clearing equations reflect the non-homogeneity of labour in the model by identifying a separate equation for each occupation category. Labour supplies of different occupations are not perfect substitutes and cannot therefore be added in a single market clearing equation. Both capital and agricultural land are modelled as industry-specific, hence separate market clearing equations are included for each industry for these input categories.

(x) Supplementary facilities

The previous parts of this section have described the main features of the ORANI theoretical structure within a framework analogous to the structure of the stylized model described earlier. This final part notes two additional facilities available in ORANI, namely a mechanism for making exogenous technological or taste changes, and the inclusion of a number of supplementary equations which are useful in manipulation of the model and in presentation of results.

The technologies of current production, capital formation and commodity distribution, and consumers' tastes are exogenous in the ORANI theory. The model does include however a facility for making technological changes in any of these processes which can be either neutral or biased in favour of some particular input. Similarly exogenous taste changes can be implemented. Using this facility it would be possible to use ORANI to investigate the effects on the economy of shocks such as a general improvement in labour productivity, a shift from usage of metals to plastics in industrial processes, a reduction in freight costs (via containerization, say) or a shift of consumers tastes in favour of imports.

Finally, the list of structural equations of the ORANI system contains a number of supplementary equations, basically of two kinds. Firstly, there are definitional equations which define useful aggregate variables in the model such as price indices, aggregate employment and the gross national product. These are especially useful in reporting the results of simulations performed with the model (see subsection 4.2). Secondly, there are a series of indexing equations which allow users to force various prices, tax rates, etc., to move with general price indexes in simulations. The most useful of these is a wage indexation equation which permits, *inter alia*, real wage rates to be held constant when domestic prices change (see subsection 4.1).

4. An ORANI Simulation : the Short-Run Effects of a 10 per cent Increase in Domestic Steel Prices

An inter-industry model like ORANI is essentially a practical device. It combines insights, derived from economic theory, about how different sectors of the economy interact with large amounts of data reflecting the operation of the interactions in the economy of interest. The role of the formal model is to process all this information and to present detailed implications of the theory and data which would not necessarily become obvious using less formal methods. In the hands of users with some experience in manipulating the model, quantitative analysis of a wide range of issues relevant to economic policy can be obtained. A number of studies of this type from ORANI have been referred to earlier in this chapter and a list of publicly documented applications was given in the introduction.

It is important to emphasize that, in order to use ORANI results legitimately, the user must be in a position to understand what features of the model's theory and data are responsible for the results. At the present stage of their development, if ever, economic models cannot claim to reflect accurately all the forces which determine the response of the economy to a given shock. The model should not, therefore, be used as a "black box" and results from it should not simply be accepted as "the answer" to the problem posed. The results can, however, be of great value to the policy analyst when understood as the implications of clearly defined mechanisms in the model. The user can then decide how much confidence to have in the results on the basis of what is taken into account in the model and can make allowance for any omitted factors which may be considered important. In order to use the model in this way, the user must first of all have at least a good general knowledge of the structure of the model. In addition he must be familiar with the special assumptions which have been made in setting up the model for the particular simulation of interest. Finally the results must be related in a fairly detailed way to the workings of the model. The value of using the model lies as much in the insights which it can give into the implications of interconnections in the economic system as in the numerical values of individual results.

An outline of the structure of ORANI was given in sub-section 3.2. This section attempts to show how the model can be used to elucidate a hypothetical economic-policy issue. In recent years the prices of major commodities, and hence the rate of return to factors engaged in their production, have increasingly become objects of government surveillance, especially in the case of commodities produced in very concentrated industries. In the Australian context, the main vehicle for such public price surveillance has been the Prices Justification Tribunal. For the purpose of illustrating the application of ORANI, the model has been used to project the short-run effects on the structure of industrial activity and employment, and on various economy-wide summary variables, of a 10 per cent increase in the domestic producer price of one major commodity, namely steel. Similar projections of the economy-wide effects of price changes under consideration might be relevant inputs to the deliberations of price-surveillance agencies.

The rest of the section is organized as follows. Subsection 4.1 contains a detailed explanation of the special assumptions about the economic environment which were imposed on the model for the purposes of simulating the effects of the steel-price increase. Users of the model have considerable scope for varying these assumptions in specifying experiments.[1] The particular assumptions chosen here are contrasted with some possibly useful alternatives. Numerical results from the illustrative application are presented and discussed in subsection 4.2.

4.1 Assumptions underlying the simulation

In section 3 (p. 44) it was noted that the number of equations in ORANI is less than the number of variables. A group of variables equal in number to the excess of the total number of variables over the number of equations in the system, must therefore be set exogenously. The model can then be used to provide solution values for the remaining (endogenous) variables. The selection of which variables are to be exogenous is of far more than just computing significance. This selection, together with the values assigned to the exogenous variables and to various user-specified parameters, is determined by the assumptions about the economic environment which are made for the simulation in hand. A key advantage of the Johansen solution method is that the model can easily be solved with different partitions of its variables into exogenous and endogenous sets. No fundamental changes to computing procedures are required when the choice of exogenous variables is changed.[2] The choice can therefore be left to the user.

The key assumptions about the economic environment which were made in simulating the effects of an increase in steel prices are as follows :

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1. This choice was discussed for the case of the stylized Johansen model in subsection 3.2(a).

2. Recall from pp. 43-45 that each new partition just requires a new division of the matrix A in equation (3.19) into the submatrices A_1 and A_2 (equations (3.20) and (3.21)).

(a) The capital and agricultural-land stocks available for use in production in each industry are fixed.

(b) Production technology and consumers' preferences are fixed.

(c) Both the level of real aggregate domestic spending and its broad composition (i.e., the shares accounted for by household consumption, investment and government expenditure) are fixed.

(d) No balance of trade constraint applies, i.e., the model is free to determine the effect of the steel-price rise on the balance of trade.

(e) The supply of labour in each of the model's nine occupations is perfectly elastic at current wage rates.

(f) Money wages are fully indexed to the ORANI index of consumer prices.

(g) The exchange rate is fixed.

The first assumption is the familiar short-run assumption of neoclassical economics. The capital stock available for use in each industry is fixed and the rental prices accruing to capital are endogenous.[1] In industries which increase their output levels in the simulation, there will be a rise in the demand for capital which will increase its rental price. Similarly a fall in an industry's output will be associated with a decrease in the rental rate on its capital. An alternative configuration of the model would make rental prices of capital exogenous and capital supply perfectly elastic at the given price. This

1. The steel industry itself is an exception in the simulation. For technical reasons associated with the exogenous treatment of the price of steel, capital usage in the industry is endogenous and the rental rate on its capital exogenous.

device would serve to simulate a Keynesian, excess-capacity economy in which industries' short-run supply curves are horizontal rather than upward sloping as in the more neoclassical environment. Note that the short-run assumption does not preclude investment. In fact, in the steel-price simulation, the level of aggregate real investment is fixed exogenously (via assumption (c)) but the industrial composition of investment and hence the pattern of demand for capital goods are allowed to respond to changes in relative rates of return induced by the rise in steel prices.[1] The short-run assumption just prevents current investment from augmenting capital stocks available for use in the solution period. The calendar-time period usually proposed for such short-run solutions is of the order of 1 - 2 years. Assumption (b) imposes restrictions on technological and taste changes which are consistent with such a short-run focus.

Assumption (c) indicates that the simulation takes no account of any effects which the change in domestic steel prices might have on aggregate domestic spending in the short run. ORANI's theoretical structure includes no mechanisms to describe short-run expenditure determination. (There is, for example, no Keynesian-style consumption function). Instead, it is assumed that aggregate expenditure is independently controlled, in the short run, by instruments of government policy (fiscal and monetary policy for example) not modelled in ORANI. As explained in subsection 3.2(b)(iii), the model is, nevertheless, constrained by an implicit national income identity equating gross domestic product to the sum of domestic absorption and the balance of trade (see equation (3.37)).

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1. Note, however, that investment is entirely exogenous for industries 17, 84 - 86, and 103 - 108 for reasons explained in subsection 3.2(b)(v). In addition, for technical reasons, the steel industry itself (63) was included in the exogenous-investment group for this simulation.

Aggregate output (i.e., GDP) is determined in the simulation mainly by supply side considerations such as fixed factor endowments (assumption (a)), technology (assumption (b)) and wage levels (assumption (f)).[1] With domestic expenditure exogenous, it is clear that the model must be allowed to determine a value for the balance of trade, hence assumption (d). An obvious alternative is to reverse the roles of domestic absorption and the balance of trade in assumptions (c) and (d), that is, to impose a balance of trade constraint and allow aggregate domestic absorption to be fixed by the model. This alternative would be more appropriate for a long-run simulation. The balance of trade constraint should then impose the long-run requirement that the country balance its overseas account allowing for likely net capital inflow and the need to remit income to foreign oweners of domestic resources.

Labour-market conditions in the chosen economic environment are determined by assumptions (e) and (f). Assumption (f) implies that real wage rates are fixed in the experiment. Alternative assumptions about the degree to which wage rates are linked to domestic prices can easily be implemented in ORANI.[2] One possibility which would often be useful for policy simulations in the current Australian environment would be to exclude the direct price effects of the policy change from the indexing formula. Given the chosen wage-indexation assumption (f), assumption (e) implies that employment levels are purely demand determined. The obvious alternative is to impose exogenous target employment levels, which may or may not represent full employment, and to allow the model to determine the change in real wage rates necessary to ensure that the demand for labour is just sufficient to generate the target levels of employment.

1. See subsection 3.2(b)(iii), especially footnote 2 on p. 64.
2. A user-specified parameter determines the level of indexation. See subsection 3.2(b)(x).

The final assumption (assumption (g)) allows the exchange rate to be used as the numeraire in the simulation. All other prices are then measured relative to the price of foreign exchange, and changes in domestic prices relative to (fixed) overseas prices are reflected in the results as changes in domestic price indexes rather than as changes in the exchange rate.[1] It is tempting to think that an alternative to assumption (g) would be to specify the balance of trade exogenously and to allow the exchange rate to vary in order to satisfy the balance of trade constraint. In fact, with wage rates indexed,[2] the balance of trade is not sensitive to changes in the exchange rate. The immediate impact of a one per cent devaluation is to cause one per cent increases in the domestic currency prices of imports and exports, but these will feed through into domestic costs via wage indexation eventually generating a one per cent increase in all domestic prices which prevents the devaluation from allowing domestic producers a competitive advantage in international trade.

The seven assumptions (a) - (g) are key assumptions which must be kept in mind in interpreting the results (in subsection 4.2) of the steel-price simulation. To summarize, those results are to be interpreted as projections of the short-run effects of an increase in domestic steel prices in an economic environment in which real wages are fixed via indexation of money wages to the domestic price level, in which there are

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1. The ORANI theory has nothing to say about how a change in domestic relative to world prices might actually be split between changes in domestic prices and changes in the exchange rate.

2. Note that the indirect tax elements of domestic costs (sales taxes, payroll tax, etc.) are also fully indexed to the domestic consumer price index in the standard version of ORANI.

no constraints on labour supply, in which aggregate domestic spending is held constant and in which the balance of trade is free to move into deficit or surplus according to the impact of the steel-price rise on the domestic demand for imports and the supply of exports.

4.2 Results

In any application of ORANI, results are computed, and can be presented, for a very wide range of variables reflecting various aspects of the economy represented in the model. For example, under the partition of variables into exogenous and endogenous sets which was chosen for the current experiment (see subsection 4.1), results are readily available for all of the following : outputs, employment, rates of return and investment for each of the model's 112 industries; outputs, basic prices, exports, imports and household consumption levels for each of the model's 114 commodity categories; land rentals in each of the model's 7 land-using agricultural industries; employment by 9 occupation groups; and various indicators of macroeconomic performance such as price indexes, aggregate trade flows, the balance of trade an an index of aggregate employment. In fact, for obvious reasons of space, this subsection contains detailed reporting of just two tables of results : a table which summarizes many of the main features of the simulation via projections for employment by occupation and some macro indicators (Table 4.1), and a table which shows the effects of the hypothetical steel-price rise on the structure of output by industry in the model (Table 4.2).

Before considering each table in detail, it is important to recap on how, in general, results from ORANI experiments should be interpreted. With the exception of the balance of trade,[1] all of the results reported are percentage changes. They are projections, conditional on the assumptions outlined in subsection 4.1, of the percentage amounts by which the values of the endogenous variables are likely to differ 1 - 2 years after the imposition of the steel-price rise from the values which they would then have taken in the absence of the price rise. The model has thus been used as a device for comparative static analysis which attempts to isolate the effects of the steel-price rise alone. The results are not intended as forecasts of the values which the endogenous variables might take at any particular calender time. To use the model in a forecasting mode would require likely values to be assigned for all of the exogenous variables at the forecast period.

(a) Macro and employment effects

Table 4.1 contains projections of the effects of the hypothetical rise in steel prices on some macroeconomic indicators and employment variables. First note that an important consequence of the rise in steel prices is to increase the level of domestic prices generally. Increases are projected in the table for both the index of consumer prices and the capital-goods price index. The direct weight of steel in these price indexes is very small since domestic steel is used predominantly as an intermediate input (87 per cent of total sales) rather than as an input to domestic final demand.[2] The price indicators are increased, however,

1. Results for this variable are always presented as changes rather than percentage changes. This is because the base-period level for the balance of trade could take the value zero.

2. Almost all of the remaining sales of domestic steel are accounted for by exports (more than 12 per cent of total sales). In this simulation steel exports are exogenous and assumed constant. Domestic steel producers are thus assumed to subsidize exports in the sense that they do not attempt to extract from foreign customers the price increase which is assumed to be levied on the domestic market.

both because producers of final goods attempt to pass on in higher prices increased costs of steel embodied in their intermediate input structures[1] and because wages are assumed to be tied to the index of consumer prices. (See assumption (f) in subsection 4.1). The wage-indexation effect raises the costs of all producers, whether or not they are direct or indirect users of steel. The fact that the capital-goods price index is projected to increase much more than the consumer-price index reflects the relatively greater importance of steel as an input to capital goods. For example, in the ORANI data base there are eleven industries for which the share of domestic steel in total costs is 5 per cent or greater.[2] Their outputs have a combined weight of 19 per cent in the capital-goods price index but only 4 per cent in the consumer price index.

The rise in domestic costs generated by the steel-price rise accounts for the contraction in aggregate employment which is projected in Table 4.1. An industry in ORANI will reduce its output (and hence, in the short run with fixed capital resources, its employment) when it experiences a deterioration in its cost/price situation. Industries facing foreign competition in their selling markets will suffer such a deterioration when domestic input costs rise. Recall from subsection 3.2(a)(ii) that the major export industries are assumed to face world prices which are not very responsive to changes in Australian export levels. Similarly, although imports and domestic supplies of importables are not assumed perfect substitutes in the model, import competitors can raise their prices

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1. Direct and indirect effects of a rise in prices via industries' intermediate input structures are what are accounted for in the input-output price model (equation (3.14)). In that model cost increases are assumed to be completely handed on.

2. They are industries 43, 65 - 70, 74 and 76 - 8. For industry descriptions, see Table 4.2.

Table 4.1 : Projections of the Short-Run Effects of a 10 per cent Increase in the Price of Domestic Steel on Macro and Employment Variables

Variable	Projection[(a)]
Aggregate employment[(b)]	- 0.17
Employment by occupation (hours worked)	
1. Professional white collar	- 0.09
2. Skilled white collar	- 0.12
3. Semi- and unskilled white collar	- 0.11
4. Skilled blue collar (metal and electrical)	- 0.30
5. Skilled blue collar (building)	- 0.07
6. Skilled blue collar (other)	- 0.09
7. Semi- and unskilled blue collar	- 0.20
8. Rural workers	- 0.34
9. Armed services	0.0
Aggregate exports (foreign currency value)	- 0.25
Aggregate imports (foreign currency value)	+ 0.41
Balance of trade	- 26.0
Index of consumer prices	+ 0.28
Index of capital goods prices	+ 0.77

(a) All projections are percentage changes with the exception of the balance of trade which has units "millions of 1968-69 Australian dollars."

(b) The index of aggregate employment is computed as a weighted average of the occupation-employment results using as weights the shares of the occupations in total persons employed.

only at the expense of some losses of market share to importers. Non-traded commodities, on the other hand, face no similar constraints in handing on increased costs in the form of higher selling prices.

The impact of the cost-price squeeze on the trading sectors is evident in Table 4.1 both in the aggregate trade projections and in the results for employment by occupation. Aggregate exports fall reflecting exporters' responses to the reduced profitability of selling to world markets at (approximately) fixed prices when domestic costs rise. Aggregate imports rise as imports gain market share at the expense of domestic producers of import-competing commodities who attempt to pass on their increased production costs. The net result of these changes in trade flows is to push the balance of trade towards deficit to the extent of \$26m.. The disaggregated employment results tell a similar story. Employment falls are most heavy in occupations 4, 7 and 8. The last of these is employed predominantly in the agricultural export industries and the other two are relatively intensively used by the metal-using, import-competing sector. By contrast occupations 1 and 5 fare comparatively well. These are used intensively in the non-trading, service and construction sectors.

Internal consistency of the aggregate employment and aggregate trade results can be checked by rough arithmetic computation of both sides of the national accounting identity (cf. the discussion of assumptions (c) and (d) in subsection 4.1). From the income side the percentage change in real GDP can be computed as the weighted sum of percentage changes in primary factor inputs, i.e.,

$$gdp = S_L \ell + S_K k + S_N n \quad , \tag{4.1}$$

where ℓ , k and n are percentage changes in the employment of labour, capital and land, and S_L , S_K and S_N are the shares of the primary factors in GDP. For the short-run experiment it is assumed that k and n are both equal to zero. Then since $S_\ell \approx 0.6$, (4.1) implies, for the value of ℓ given in Table 4.1 (i.e., - 0.17) that the percentage change in the GDP is about 0.10. From the expenditure side the percentage change in GDP is computed as

$$gdp = S_A a + S_E e + S_M m \quad , \tag{4.2}$$

where a , e and m are the percentage changes in aggregate real absorption, exports and imports , and S_A , S_E and S_M are the shares of the expenditure categories in GDP. Given the assumption of fixed absorption (a = 0), the values of the aggregate trade flows from Table 4.1 (i.e., e = - 0.25 and m = 0.41) and the weights $S_E = 0.137$ and $S_M = - 0.150$ from the ORANI data base,[1] (4.2) yields a value for the percentage change in the GDP of about 0.096 . The check is thus satisfactory.

The general implication of Table 4.1 is that, for an internationally trading nation like Australia, there are always short-run gains, in terms of employment and the balance of trade, from holding down the prices of important items in the domestic cost structure. This is especially so when cost increases arising in any one sector are rapidly spread via wage indexation. The most important contemporary context for this idea is that of the appropriate pricing policy for domestically

1. Note that the data base shows a slight deficit on the balance of trade.

produced crude oil.[1] The problem with the short-run analysis is that it completely omits the long term, resource-allocative consequences, usually taken to be adverse, of interfering with the price mechanism.

(b) Industry-output projections

Table 4.2 contains projections of the percentage effects of the 10 per cent increase in steel prices on the output level of each of ORANI's 112 industries. The projections appear in ranked order with the industry whose output is projected to decline most severely (industry 63, Basic Iron and Steel) ranked "1" and the industry which is projected to suffer least from the price rise (industry 106, Health) ranked "112". Each industry is assigned to one or more of four trade classifications : import-competing (IC), export (E), export related (ER) and non-trading (NT). Industries assigned to the IC category face significant import shares in their selling markets and/or large elasticities of substitution between their outputs and imports of the same commodity category.[2] Industries designated E are those for which exports are endogenous in the simulations. The ER industries do not export directly but sell large shares of their outputs to the exporters. Industry 4 (Northern Beef) is a good example. It sells most of its output to the exporter 18 (Meat Products). Industries are classified as NT if they have not been assigned to any other group, i.e., when their links with international trade are very weak.

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1. See Vincent, Dixon, Parmenter and Sams (1979) and Higgs (1980).

2. These two factors determine the strength of the import substitution effects in the ORANI demand equations (see subsection 3.2(b)(ii)).

Table 4.2 : Short-Run Effects on Industry-Output Levels of a 10 per cent Increase in the Producer Price of Domestic Steel (Industries ranked in inverse order of output change)

Rank	ORANI Code	INDUSTRY Description	Projection (per cent)	Trade Category [1]	Rank	ORANI Code	INDUSTRY Description	Projection (per cent)	Trade Category [1]
1	63	Basic Iron & Steel	-.793	IC	31	4	Northern Beef	-.168	ER
2	68	Motor Vehicles, Parts	-.751	IC	32	44	Pulp, Paper	-.162	IC
3	67	Metal Products n.e.c.	-.729	IC	33	43	Furniture, Mattresses	-.159	IC
4	14	Coal	-.723	E	34	36	Textile Products n.e.c.	-.153	IC
5	64	Other Basic Metals	-.591	E	35	57	Glass	-.148	IC
6	25	Food Products n.e.c.	-.519	E	36	49	Chemical Fertilisers	-.148	ER
7	76	Agricultural Machinery	-.513	IC,ER	37	9	Services to Agriculture	-.143	ER
8	74	Household Appliances	-.427	IC	38	81	Plastic Products	-.140	IC
9	78	Other Machinery	-.363	IC	39	41	Plywood, Veneers	-.136	IC
10	77	Construction Equipment	-.340	IC,ER	40	66	Sheet Metal Products	-.125	IC
11	11	Fishing	-.335	E	41	93	Road Transport	-.125	ER
12	13	Other Metallic Minerals	-.324	E	42	95	Water Transport	-.124	IC,ER
13	50	Industrial Chemicals	-.272	IC	43	40	Sawmill Products	-.122	IC
14	69	Ship & Boat Building	-.262	IC,ER	44	39	Footwear	-.109	IC
15	65	Structural Metal	-.262	IC	45	45	Fibreboard	-.108	IC
16	6	Other Farming Export	-.245	ER	46	2	Wheat/Sheep Zone	-.108	E
17	55	Chemical Products n.e.c.	-.230	IC	47	1	Pastoral Zone	-.106	E
18	31	Man-Made Fibres, Yarn	-.230	IC	48	83	Other Manufacturing	-.099	IC
19	30	Prepared Fibres	-.228	E	49	79	Leather Products	-.095	IC
20	75	Electrical Machinery	-.227	IC	50	21	Margarine, Oils and Fats	-.095	IC
21	70	Locomotives	-.220	ER	51	58	Clay Products	-.091	IC
22	82	Signs, Writing Equipment	-.212	IC	52	112	Business Expenses	-.084	NT
23	3	High Rainfall Zone	-.208	E	53	52	Pharmaceuticals	-.083	IC
24	73	Electronic Equipment	-.205	IC	54	89	Wholesale Trade	-.083	NT
25	32	Cotton, Silk and Flax	-.197	IC	55	48	Commercial Printing	-.082	IC
26	18	Meat Products	-.189	E	56	16	Non-Metallic Minerals n.e.c.	-.079	IC
27	51	Paints, Varnishes	-.185	NT	57	71	Aircraft Building	-.079	IC
28	94	Railway Transport	-.183	ER	58	101	Investment, Real Estate	-.076	NT
29	10	Forestry	-.178	NT	59	47	Newspapers and Books	-.075	IC
30	80	Rubber Products	-.176	IC	60	84	Electricity	-.073	NT

continued ...

Table 4.2 continued ....

Rank	ORANI Code	INDUSTRY Description	Projection (per cent)	Trade Category [1]	Rank	ORANI Code	INDUSTRY Description	Projection (per cent)	Trade Category [1]
61	5	Milk Cattle	-.072	ER	86	33	Wool & Worsted Yarns	-.038	IC
62	98	Banking	-.072	NT	87	22	Flour & Cereal Products	-.034	NT
63	62	Non-Metallic Mineral Products	-.071	IC	88	86	Water, Sewerage	-.029	NT
64	72	Scientific Equipment	-.069	IC	89	109	Entertainment	-.027	IC
65	34	Textile Finishing	-.068	IC	90	38	Clothing	-.026	IC
66	102	Other Business Services	-.067	NT	91	24	Confectionery	-.024	IC
67	35	Textile Floor Coverings	-.067	IC	92	37	Knitting Mills	-.023	IC
68	92	Other Repairs	-.067	NT	93	53	Soap & Detergents	-.023	IC
69	56	Oil & Coal Products	-.066	IC	94	99	Finance & Life Insurance	-.016	NT
70	15	Crude Oil	-.066	NT	95	108	Welfare Services	-.016	NT
71	20	Fruit & Vegetable Products	-.064	NT	96	61	Concrete Products	-.015	NT
72	28	Alcoholic Drinks n.e.c.	-.059	IC	97	90	Retail Trade	-.011	NT
73	8	Poultry	-.059	ER	98	27	Beer & Malt	-.006	NT
74	46	Paper Products n.e.c.	-.056	IC	99	19	Milk Products	-.005	NT
75	7	Other Farming Import Competing	-.055	NT	100	54	Cosmetics, Toiletry	-.004	IC
76	91	Motor Vehicle Repair	-.054	NT	101	104	Public Administration	-.003	NT
77	97	Communication	-.051	NT	102	23	Bread, Cakes	-.001	NT
78	42	Joinery & Wood Products	-.051	IC	103	107	Education, Libraries	-.000	NT
79	59	Cement	-.048	NT	104	103	Ownership of Dwellings	0.000	NT
80	17	Services to Mining	-.047	NT	105	105	Defence	0.000	NT
81	96	Air Transport	-.046	IC	106	87	Residential Building	0.000	NT
82	100	Other Insurance	-.045	NT	107	29	Tobacco	.000	NT
83	85	Gas	-.044	NT	108	60	Ready-Mixed Concrete	.001	NT
84	12	Iron	-.043	E	109	110	Restaurants, Hotels	.001	NT
85	26	Soft Drinks, Cordials	-.039	NT	110	111	Personal Services	.006	NT
					111	88	Building n.e.c.	.008	NT
					112	106	Health	.013	NT

1. Abbreviations used are

IC = import-competing
E = export
ER = export-related
NT = non-trading.

The general structure of the ranked table can be anticipated from the description of the macro and employment results given in the previous subsection. Internationally trading industries appear high in the ranking especially if steel is important, directly or indirectly, in their intermediate input structures. Since aggregate domestic spending is held constant, industries which serve domestic final demand and do not face significant import competition take low places in the ranking. The purpose of this subsection is to expand on the implications of these general factors for the industrial structure defined at the ORANI level of disaggregation and to demonstrate some of the features of the model's structure and data base which account for the relative positions of individual industries within these general categories.

The steel industry itself (industry 63) is projected to experience the greatest decline in output following the hypothetical rise in its selling prices. With the steel prices set exogenously, the change in steel output reflects the response of domestic steel users to the higher price. The market-clearing constraint for domestic steel implies that the sum of changes in intermediate demand for steel and exports of steel,[1] each weighted by their shares in total steel sales, must be equal to the percentage change in the output of steel. Exports are assumed to be constant so that the projected decline in steel output (Table 4.2) is consistent with a decrease in intermediate usage of domestic steel of approximately 0.9 per cent.[2] The ORANI theory (see subsections 3.2(b)(ii) and 3.2(b)(vi)) implies that intermediate input demand functions for domestic commodities take the form

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1. Recall that the intermediate and export markets account for virtually all the sales of domestic steel (see p. 87, including footnote 2).

2. The share of intermediate usage in total sales of steel is 0.87.

$$x_{(i1)j} = z_j - \sigma_i \, S_{(i2)j}(p_{(i1)j} - p_{(i2)j}) \ . \qquad (4.3)$$

That is, the percentage change $(x_{(i1)j})$ [1] in the demand for domestically produced good i by industry j depends on the percentage change in the output of the using industry (z_j) and , since substitution between imports and domestic supplies is allowed, on the percentage change in the purchasers' price of domestic supplies relative to imports $(p_{(i1)j} - p_{(i2)j})$. The parameters σ_i and $S_{(i2)j}$ in equation (4.3) are respectively the elasticity of substitution for user j between the two sources of input i and the share of imports in j's total usage of i . A rough explanation of the result for steel can be given by computing numerical values for the terms in (4.3) using values for the parameters from the ORANI data base. Approximate average values for all intermediate users for the percentage changes in purchasers' prices are $p_{(i1)j} \simeq 9.03$ and $p_{(i2)j} \simeq 0.03$. [2] From the data base, $\sigma_i = 0.5$ for all j [3] and the average value (over j) of $S_{(i2)j}$ is 0.11. Hence, the second term on the RHS, i.e., the substitution term, of (4.4) is approximately equal to 0.50. This leaves a decline of 0.4 per cent in total intermediate usage of steel to be accounted for by the activity-level term (z_j) . More than 50 per cent of the total intermediate usage of steel is accounted for by

1. The subscript (i1) is used to indicate domestic good i , and (i2) to indicate imports of good i .

2. These are computed as weighted sums of the percentage changes in basic value prices and margins costs. The percentage changes in the basic value prices of domestic and imported steel are 10 and 0 respectively and the cost of margins is assumed, for the purposes of the explanatory calculation, to move in line with the domestic consumer price index (i.e., 0.28 per cent, see Table 4.1). The share of basic value in purchasers' prices is 0.9 for both imports and domestic supplies. (Cf. subsection 3.2(b)(viii) especially equation (3.42)).

3. This relatively low value for the elasticity of substitution is used in ORANI to reflect the fact that imports of steel are typically of different product lines than domestic output.

sales to industries experiencing output declines in excess of 0.4 per cent (i.e., by industries ranked 1 - 8 in Table 4.2). A weighted average value of 0.4 for the z_j in equation (4.3) for the case of steel usage is thus quite plausible.

Examination of the results for the remaining 11 of the 12 main losers in the steel-price simulation provides a good illustration of the importance of accounting for factors beyond input-output linkages to the steel industry. Of those industries ranked 2 - 12 in Table 4.2, for only 6 (i.e., industries 68, 67, 76, 74, 78 and 77) is the direct impact of increased steel costs an important factor. All 6 of these are import-competing industries with shares of steel in total costs 5 per cent or greater. Even within this group, factors other than the weight of steel in total costs can predominate in explaining relative output performance. For example, the Motor Vehicle industry (68) ranks higher (2nd) than the Metal Products industry (67) (which is ranked 3rd), despite the fact that steel accounts for only 5 per cent of the costs of motor vehicles but 17 per cent of those of metal products. The reason is that the Motor Vehicles industry faces much stiffer import competition, according to the ORANI data base, than does the Metal Products industry. The share of imports in the market facing both industries is about 20 per cent but the estimated elasticity of substitution between imports and domestic output is 5 for the case of motor vehicles but only 2 for metal products.

The remaining 5 of the 12 highest ranked industries in Table 4.2 (i.e., 14, 64, 25, 11 and 13) are all export industries [1] without strong intermediate-cost linkages to steel. The main impact of the

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1. That is, their export levels are determined exogenously in the simulation (see subsection 3.2(b)(ii)).

steel-price rise on their costs is via labour costs and wage-indexation. As export industries facing elastic foreign demand curves they are, however, especially vulnerable to cost pressures. The adverse impact of general cost pressures on the export sector is a further factor (additional to the incidence of import competition) in the explanation of the high positions of the Agricultural Machinery (76) and Construction Equipment (77) industries in the table. These industries have important linkages to exports as suppliers of inputs to capital formation in the agricultural and mining export sectors. One effect of the steel-price rise is to cause a reallocation of the economy's investment budget away from the trading sectors. The demand for capital goods produced by these two industries declines accordingly.

Looking beyond the first twelve industries in Table 4.2, several other features of ORANI can be shown to be influential in determining the relative responses of industries, within the broad trade classifications, to the hypothetical steel-price rise. The first is capital and land intensity. In short-run ORANI simulations, industries employing high ratios of these fixed factors in total primary costs have little scope to respond to a cost-price squeeze by reducing output and factor inputs.[1] The return to fixed factors will fall but in the short run they are committed to the industry. The export industries exhibit the influence of this most

1. In fact, the CES, primary-input production functions in ORANI imply that the short-run elasticity of output with respect to value added price in industry j is given

$$e_j = \frac{\sigma_j^P S_{Lj}}{1 - S_{Lj}} ,$$

where σ_j^P is the pairwise elasticity of substitution between primary factors in industry j, and S_{Lj} is the share of labour in industry j's total primary costs.

clearly. The Iron industry (12) is the most fixed-factor intensive of these but the agricultural exporters[1] in the Pastoral Zone (1), the Wheat-Sheep Zone (2), and the High Rainfall Zone (3), because of the presence of land in their input structures, have, on average, higher shares of fixed factors than the non-rural exporters. Correspondingly, these four industries rank, in turn, 84th, 47th, 46th and 23rd[2] - much lower than the remaining exporters. A further factor which helps to explain the comparatively good performance of the three agricultural zones (industries 1 - 3) is the importance of wool in their exports. Because of Australia's large share in world wool supplies, the elasticity of demand for wool exports is assumed to be significantly lower than for all other export commodities. The foreign demand elasticity facing exporters of prepared wool fibres (industry 30) is also low relative to other non-wool exporters.

Within the import-competing sector it is evident that usage of traded inputs, whose costs are held down relative to the general level of domestic costs by international competitive pressures, tends to cushion some industries from the indirect effects of the steel-price rise. Thus industries high in the textiles chain such as Clothing (38) and Knitting Mills (37) which use other textile inputs, appear lower in the ranking of Table 4.2 than do their suppliers, Cotton, Silk and Flax (32) and Man-made Fibres and Yarn (31) for example.

Finally, the non-trading industries fall roughly into two groups, those which produce mainly intermediate goods or services and those which supply domestic final demand directly. On average the former are

1. These are the three multi-product agricultural industries in ORANI for which transformation frontier parameters have been estimated (see sub-section (3.2)(b)(vii). Large shares of their outputs are accounted for by the export commodities, wool and grains.

2. Note that, within agriculture, industry 3 is more labour intensive than either 1 or 2.

ranked higher in Table 4.2. Examples are Business Expenses (112), Wholesale Trade (89), Investment and Real Estate (101) and Other Business Services (107). As would be expected, since these industries supply inputs to most domestic producers their own output changes tend towards the average output change for the economy, i.e., about - 0.1 per cent. The average change in domestic final demand on the other hand is zero because the domestic spending aggregates are fixed exogenously in the simulation. Non-trading industries which supply only or predominantly government final demand, the structure as well as the aggregate level of which is exogenous, experience almost no change in output. The main examples are Defence (105), Education and Libraries (107) and Public Administration (104). Non-trading, investment-goods suppliers (88, 60 and 61 for example) show minor output changes in response to the realloca-tion of the economy's fixed aggregate investment budget between industires with different capital structures. The variation in the performance of the non-trading suppliers of domestic household consumption is explained by minor reallocations of the consumers' budget in response to changes in relative prices induced as a consequence of the cost effects of the steel-price increase.

5. Concluding Remarks

The main purposes of this chapter have been to show the importance of accounting for inter-industry linkages in policy-oriented economic analysis and to illustrate how the implications of the linkages can be traced out via formal economic models. Examples were discussed in general terms of the usefulness of inter-industry methods in the analysis both of changes in industry policy (e.g., tariff changes) and also of the effects on the economy of exogenous developments in a single sector (e.g., a mining boom). As well as these general examples a specific case study was presented (section 4) in which the short-run effects of a rise in steel prices was analysed using the multisectoral ORANI model.

The case study in section 4 served to emphasize the role of indirect effects in determining the impact on the economy of the steel-price rise but its primary function was as an illustration of how the ORANI model can be used. As a tool for policy analysis, a Johansen-style model such as ORANI has a number of advantages. The model is a general purpose model which employs a linear solution procedure allowing modifications or extensions to be made easily when these are required to adapt the model to new problems. The structure of the model is quite simple : in fact many of its main features were adequately illustrated using a very simple "stylized" version (Section 3.2(a)). The value of structural simplicity is that results remain easily interpretable in terms of the economics underlying the system, even in a model which is very large and detailed with respect to the number of sectors distinguished, the amount of data incorporated , etc.. The result-interpretation stage is essential in using the model for two reasons. Firstly, it provides a constant check on the implementation and computing procedures employed with the model. With large systems the scope for problems arising in these procedures is very great. Secondly, interpretation highlights the insights into the working of the economy which the model suggests rather than the precise numerical values of the results. It is important to be able to understand which of the many mechanisms built into the model are dominant in producing any given result. Simplifications in the model's theoretical structure and data limitations will always mean that exact numerical values of results should be approached with some caution. If the user understands how features of the model have contributed to the results, doubts about the exact numbers can often be resolved by sensitivity analysis.

Appendix A: Derivation and Linearization of the Stylized Johansen Model

1. Consumers' demand

The consumers' utility-maximization problem is

Choose

X_{10} and X_{20} to maximize

$$U = X_{10}^{\alpha_{10}} X_{20}^{\alpha_{20}} , \tag{A1}$$

subject to

$$P_1 X_{10} + P_2 X_{20} = Y , \tag{A2}$$

where

$$0 < \alpha_{i0} < 1 ,$$

and

$$\sum_{i=1}^{2} \alpha_{i0} = 1 .$$

Form the Lagrangean

$$L = X_{10}^{\alpha_{10}} X_{20}^{\alpha_{20}} + \lambda(Y - P_1 X_{10} - P_2 X_{20}) , \tag{A3}$$

where λ is a Lagrangean multiplier (interpretable as the marginal utility of income).

The first order conditions, for maximization of L are

$$\frac{\partial L}{\partial X_{10}} = \alpha_{10} X_{10}^{(\alpha_{10}-1)} X_{20}^{\alpha_{20}} - \lambda P_1 = 0 , \tag{A4}$$

$$\frac{\partial L}{\partial X_{20}} = \alpha_{20} X_{10}^{\alpha_{10}} X_{20}^{(\alpha_{20}-1)} - \lambda P_2 = 0 , \tag{A5}$$

and

$$\frac{\partial L}{\partial \lambda} = Y - P_1 X_{10} - P_2 X_{20} = 0 . \tag{A6}$$

Eliminate λ by dividing (A4) by (A5) to give

$$\frac{\alpha_{10}}{\alpha_{20}}\frac{X_{20}}{X_{10}} = \frac{P_1}{P_2} . \qquad \text{(A7)}$$

Solve (A7) for X_{20}, substitute into (A6) and solve for X_{10}. Noting that $\alpha_{10} + \alpha_{20} = 1$, this yields

$$X_{10} = \alpha_{10}\, Y/P_1 , \qquad \text{(A8)}$$

and a similar procedure gives

$$X_{20} = \alpha_{20}\, Y/P_2 . \qquad \text{(A9)}$$

Equations (A8) and (A9) are equivalent to equation (3.24) in the text.

2. Input demands

The producers cost-minimization problem is

Choose

X_{ij} to minimize

$$C_j = \sum_{i=1}^{4} P_i . X_{ij} , \qquad \text{(A10)}$$

subject to

$$X_j = A_j \prod_{i=1}^{4} X_{ij}^{\alpha_{ij}} , \qquad \text{(A11)}$$

where

$$0 < A_j ,$$

$$0 < \alpha_{ij} < 1 ,$$

and

$$\sum_{i=1}^{4} \alpha_{ij} = 1 .$$

Form the Lagrangean

$$L_j = \sum_{i=1}^{4} P_i X_{ij} + \lambda_j (X_j - A_j \prod_{i=1}^{4} X_{ij}^{\alpha_{ij}}) \quad , \qquad \text{(A12)}$$

where λ_j is a Lagrangean multiplier (interpretable as marginal cost of output).

The first order conditions for minimization of L_j are

$$\frac{\partial L_j}{\partial X_{ij}} = P_i - \lambda_j \left(\frac{A_j \alpha_{ij}}{X_{ij}} \prod_{k=1}^{4} X_{kj}^{\alpha_{kj}} \right) = 0 \; , \qquad i = 1, \ldots, 4 \; , \qquad \text{(A13)}$$

$$\frac{\partial L_j}{\partial \lambda_j} = X_j - A_j \prod_{i=1}^{4} X_{ij}^{\alpha_{ij}} = 0 \; . \qquad \text{(A14)}$$

Rearrange (A13) to give

$$\frac{P_i X_{ij}}{\alpha_{ij}} = \lambda_j A_j \sum_{k=1}^{4} X_{kj}^{\alpha_{kj}} \; . \qquad \text{(A15)}$$

Note that the RHS of (A15) is independent of i so that we can write for any arbitrary $k = 1, \ldots, 4$,

$$\frac{P_i X_{ij}}{\alpha_{ij}} = \frac{P_k X_{kj}}{\alpha_{kj}} \qquad (i \neq k) \quad , \qquad \text{(A16)}$$

which implies

$$X_{ij} = \frac{P_k X_{kj} \alpha_{ij}}{P_i \alpha_{kj}} \; . \qquad \text{(A17)}$$

Substitute (A17) into (A15) and solve for X_{kj} , noting that

$\sum_i \alpha_{ij} = 1$, to give

$$X_{kj} = Q_{kj} X_j \prod_{t=1}^{4} P_t^{\alpha_{tj}} / P_k \qquad (k = 1, \ldots, 4) \quad , \tag{A18}$$

where

$$Q_{kj} = \alpha_{kj} \left(\prod_{t=1}^{4} (\alpha_{tj})^{-\alpha_{tj}} \right) \Big/ A_j \quad . \tag{A19}$$

Equations (A18) and (A19) are the result given in equations (3.27) and (3.28) in the text.

Finally, note that the α_{kj} are cost shares. That is, substituting (A19) back into (A18) and solving for $P_k X_{kj}$ gives

$$P_k X_{kj} = \alpha_{kj} \left[X_j \prod_{t=1}^{4} (\alpha_{tj})^{-\alpha_{tj}} \prod_{t=1}^{4} P_t^{\alpha_{tj}} \Big/ A_j \right] \quad , \tag{A20}$$

where the term in square brackets on the RHS is independent of k . Therefore dividing (A20) by its sum over k and recalling that $\sum_{k=1}^{4} \alpha_{kj} = 1$ gives ,

$$\frac{P_k X_{kj}}{\sum_{k=1}^{4} P_k X_{kj}} = \alpha_{kj} \quad , \tag{A21}$$

which is the result given in equation (3.29) in the text.

3. Pricing equations

Substitute equation (3.27) from the text into equation (3.30) to give

$$P_j X_j = \sum_{i=1}^{4} \left\{ P_i Q_{ij} X_j \prod_{t=1}^{4} P_t^{\alpha_{tj}} \Big/ P_i \right\} . \qquad \text{(A22)}$$

The P_i cancel immediately from the RHS of (A22). The term $X_j \prod_{t=1}^{4} P_t^{\alpha_{tj}}$ is independent of i and can therefore be taken outside the summation allowing the X_j to cancel yielding

$$P_j = \left(\sum_{i=1}^{4} Q_{ij} \right) \prod_{t=1}^{4} P_t^{\alpha_{tj}} ,$$

which is equation (3.31) in the text.

4. Walras' Law

Multiply equations (3.32) and (3.33) in the text by the P_i to give

$$P_i X_i = \sum_{j=0}^{2} P_i X_{ij} \qquad (i = 1, 2) , \qquad \text{(A23)}$$

and

$$P_i X_i = \sum_{j=1}^{2} P_i X_{ij} \qquad (i = 3, 4) . \qquad \text{(A24)}$$

Add (A23) to (A24) to give

$$\sum_{i=1}^{4} P_i X_i = \sum_{i=1}^{2} P_i X_{i0} + \sum_{i=1}^{4} \sum_{j=1}^{2} P_i X_{ij} . \qquad \text{(A25)}$$

Substitute equation (3.30) from the text into (A25), yielding

$$\sum_{i=1}^{4} P_i X_i = \sum_{i=1}^{2} P_i X_{i0} + \sum_{j=1}^{2} P_j X_j \quad . \tag{A26}$$

Transpose the second term on the RHS of (A26) so that

$$\sum_{i=3}^{4} P_i X_i = \sum_{i=1}^{2} P_i X_{i0} \quad . \tag{A27}$$

Finally substitute (3.24) from the text into (A27) which, recalling that $\sum_{i=1}^{2} \alpha_{i0} = 1$ yields

$$\sum_{i=3}^{4} P_i X_i = Y \quad ,$$

as in equation (3.34) in the text.

5. Linearization

Equations (3.24), (3.27), (3.31), (3.32), (3.33) and (3.35) were transformed to the linear proportional-change versions by application of the following rules which follow from the standard rules of differentiation. The notation

$$x = dX/X$$

is used.

$$\frac{d(X_1 X_2)}{X_1 X_2} = x_1 + x_2 \quad , \tag{A28}$$

$$\frac{d(X_1 + X_2)}{(X_1 + X_2)} = \frac{X_1}{(X_1 + X_2)} x_1 + \frac{X_2}{(X_1 + X_2)} x_2 \tag{A29}$$

and

$$\frac{d(X^{\alpha})}{X^{\alpha}} = \alpha x \quad . \tag{A30}$$

Note that (A28) and (A30) imply

$$\frac{d(X_1/X_2)}{(X_1/X_2)} = \frac{d(X_1\ X_2^{-1})}{(X_1\ X_2^{-1})} = x_1 - x_2 \quad . \tag{A31}$$

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