IMPACT OF DEMOGRAPHIC CHANGE ON INDUSTRY STRUCTURE IN AUSTRALIA

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NOTES ON THE THEORY OF LONG-RUN SIMULATIONS WITH THE ORANI MODEL

by

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Abstract

ORANI is a disaggregated general equilibrium model of the Australian economy developed as part of the IMPACT Project. It can be run either under short-run assumptions of fixed, industry-specific capital stocks or in long-run mode with capital stocks endogenous. This paper shows how the long-run effects of an exogenous shock delivered in the base year can be simulated either by accumulation through successive single period solutions or via a "snapshot" approach. Mechanisms introduced into the model to avoid the tendency to over-specialization often experienced in long-run models emphasizing international trade are also discussed.

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1. INTRODUCTION

1.1 Applications of ORANI in short-run mode

Over the past year the short-run version of the ORANI model has become operational on a routine basis.[1] Applications have included the following[2] :

(i) a simulation of the effects of a devaluation on industry outputs, employment, the price level and the balance of trade under conditions of 70 per cent wage indexation ,

(ii) a simulation of the effects of a uniform across the board increase in tariffs on industry outputs, employment, etc. ,

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1. ORANI is a disaggregated general equilibrium model of the Australian economy. The theory and data input for the currently operational version is fully described in Dixon, Parmenter, Ryland and Sutton [1977] (hereafter DPRS). The computer programmes are explained in Sutton [1977]. ORANI has been developed as part of the IMPACT Project. For a complete but non-technical description of IMPACT Powell [1977].

2. Applications of ORANI are reported in Powell [1977], DPRS, Dixon, Harrower and Powell [1977], Dixon, Parmenter and Sutton [1977, 1978a, 1978b], Powell and Parmenter [1978] and Industries Assistance Commission [1977]. A short summary of the applications and results appears in Dixon [1978b, section 3].

(iii) a simulation of the effects of increased export revenue (resulting from the mining boom) on industry outputs, employment, etc. ,

(iv) a simulation of the effects of the wage explosion and equal pay for women on industry outputs, employment, etc. ,

(v) a simulation of the effects of changes in Australia's terms of trade on industry outputs, employment, etc. .

A recent extension of the model has allowed disaggregation of these results to the state level.[1] For example, we are able to look at the effects of tariff changes on economic activity in Queensland, Western Australia, etc..

With only one exception (Dixon, Harrower and Powell [1977]), ORANI has been used in short-run mode for all of these applications. By short-run mode, we refer to simulations in which industry capital stocks are held fixed. To take a specific example, in DPRS we investigated the "short-run" impact of a one per cent increase in all tariffs. The computations showed the changes in industry outputs, employment, rates of return, investment, etc., which could be expected to take place as a result of the tariff increase over a period of time sufficiently short that capital stocks could be considered unaffected. That is, we let the tariff increase alter investment plans, but we did not allow for the impact of the changed investment plans on capital stocks.

1. The theoretical background and preliminary applications of the regional facility are described in Dixon, Parmenter and Sutton [1978b]. Our method for regionalizing ORANI results follows closely the well-known regional-balance method of Leontief _et al._ [1965].

importantly), an accumulation approach places a rather heavy burden on a model's short-run investment mechanism. An investment story which provides satisfactory simulations for the short-run may not be suitable for the long-run. Accumulation of short-run investment simulations may lead to accumulation of unacceptable long-run errors.

checking the correlations between genuine long-run results and the short-run indicators. In section 3.3 we outlined progress to date in incorporating diversifying factors into the ORANI model. The long-run capabilities of ORANI are gradually being extended as we add results from relevant econometric studies. In particular, we discussed the CRESH-CRETH study of Australian agriculture and the work of Alaouze, Marsden, Milkovits and Zeitsch on substitution elasticities between domestic and foreign sources of supply. We should also mention the recent study by the Bureau of Industry Economics[1] on long-run technological change. ORANI is currently been revised to allow it to accept scenarios concerning changes in production technology.[2] When these revisions are completed, it will be possible to use the work of the Bureau of Industry Economics in ORANI to obtain long-run projections of the impact of technological change on industry structure.

One final comment concerns the relationship between long-run strategies one and two (accumulation through time and snapshot). It is to be hoped that the two approaches give similar results. As the long-run capability of ORANI is extended, we will be making the relevant comparisons. However, there are two reasons for preferring snapshot to accumulation. First, the computing of snapshot solutions is very straightforward : we remain in the one period framework. Second, (and more

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1. See Chapman and Wood [1978a, b and c].
2. See Dixon [1978a].

For many purposes, the short-run mode is quite adequate and appropriate. Policy makers concerned with macroeconomic management are usually interested in achieving satisfactory levels of utilization of existing capital. Questions of the longer run implications of policy initiatives for capital accumulation and its allocation across industries are put to one side. For example, changes in capital stocks would only be of peripheral importance in a debate on the appropriate policies for achieving balanced (in the sense of a reasonably uniform stimulation of all industries and regions) macroeconomic recovery in Australia over the next eighteen months. On the other hand for many economic issues, long-run analysis is required : the implications of technological change, the welfare costs of protection, the economic effects of demographic change to name just a few.

There are several strategies for long-run modelling. Among these are the following :

(i) accumulation through time ,

(ii) the snapshot approach ,

(iii) the short-run indicator of long-run consequences .

Before we discuss each of these in the context of ORANI, it will be useful to set out some notation and other background material.

1.2 <u>Schematic algebraic representation of ORANI</u>

We represent the model by

$$Az(t) = 0 \tag{1.1}$$

where A is a $m \times n$ matrix and $z(t)$ is the $n \times 1$ vector of variables for time t. The number of variables n exceeds the number of equations m. In the current version of the model

$$n - m = 900 .$$

The model is closed by declaring $(n-m)$ variables to be exogenous. Then we solve by

$$A_1 z_1(t) + A_2 z_2(t) = 0 \tag{1.2}$$

and

$$z_1(t) = - A_1^{-1} A_2 z_2(t) \tag{1.3}$$

where $z_2(t)$ is the $(n-m)$ vector of exogenous variables and $z_1(t)$ is the $m \times 1$ vector of endogenous variables. A_1 and A_2 are submatrices formed from the appropriate columns of A.

All the variables of the model (except one)[1] are percentage changes, i.e., the equations are relationships between percentage changes in prices, outputs, employment, exports, imports, etc.[2] Hence, the elements of the matrix $- A_1^{-1} A_2$ may be interpreted as elasticities : the i,jth element is the elasticity of endogenous variable i with respect to exogenous variable j -- the elasticity of professional employment with respect to the tariff on motor vehicles, etc..

1. The exception is the balance of trade. ORANI includes the change, rather than the percentage change in the balance of trade. Obvious difficulties arise in interpreting percentage changes in variables whose levels can change signs.

2. ORANI belongs to the Johansen class of models, so named in recognition of the pioneering contribution of Johansen [1960].

between industries in the long-run. Both strategies can lead to over-specialization problems in models where phenomena explaining long-run diversification of industrial activity are inadequately handled. Since these phenomena (e.g., terms of trade effects, specialized factors such as land and mines, and differences in the properties of domestic products and their competitive imports) are difficult to cope with, especially from the empirical point of view, there is a temptation to rely on our third strategy for long-run analysis.

The third strategy involves using short-run results as long-run indicators. With short-run simulations, overspecialization problems do not arise because we restrict the mobility of capital. However, this third strategy involves at least one act of faith and provides only limited information about the long-run consequences of the policy or other changes under consideration. The act of faith is that the long-run consequences for relative growth prospects across industries are closely correlated with the short-run consequences for such indicators as industry outputs, rates of return, investment, etc.[1] Even if this is accepted, the short-run indicator strategy provides limited information because it cannot tell us how large the long-run impacts are likely to be.

Ideally, long-run simulations should be made with models which take adequate account of long-run diversifying factors. Then strategy three becomes unnecessary, although there would be some interest in

1. It is reassuring to note that ORANI generally indicates high correlations between the short-run results for the various variables which could be used as long-run indicators.

Features (i) and (ii), (i.e., the imperfect substitution between imports and domestic production and less than infinite foreign demand elasticities are part of the 1977 version of ORANI (see DPRS). Trials using the revised model incorporating CRESH-CRETH are currently underway. With the 1977 model, there are no flip-flop problems on the import side -- the inclusion of estimated substitution elasticities between domestic supplies and competitive imports allows ORANI to imply plausible long-run behaviour for import shares in domestic markets. On the other hand, in the 1977 version of ORANI we have found it to be necessary to exogenize exports in long-run simulations.[1] Without some artificial help, the 1977 model tends to imply extreme commodity specialization within the economy's export bundle. (This is in spite of the less than infinite foreign demand elasticities for Australian products.) The addition of CRESH-CRETH to the model will eliminate the problem with regard to agricultural exports. However, for the other exports, (mining and manufacturing) we expect that long-run ORANI simulations will continue, for sometime, to reflect the imposition of some fairly arbitrary constraints.

4. CONCLUDING REMARKS

In this paper we have outlined three strategies for long-run simulations with the ORANI model. The first two, accumulation through time and the snapshot approach, both recognize that capital is mobile

1. See Dixon, Harrower and Powell [1977].

1.3 Switching variables between the exogenous and endogenous categories

A feature of ORANI is that the division between endogenous and exogenous variables is user-determined. For example, in a study of the effects of tariff changes on industry outputs, the tariffs would be part of the z_2 vector while industry outputs would be in z_1. On the other hand, if we wanted to know what level of protection would be required in the footwear industry to boost its output by 5 per cent, then the footwear tariff would appear among the endogenous variables while footwear output would be exogenous. Another obvious switch between endogenous and exogenous variables involves the balance of trade and the level of domestic absorption. In some simulations we fix the level of domestic absorption (i.e., the macro aggregates such as total household expenditure are part of z_2) whereas in others we allow domestic absorption to adjust to achieve an exogenously given balance of trade. Of particular relevance to the current discussion are switches involving rates of return and capital stocks. In short-run mode, capital stocks are exogenous and rates of return are endogenous. We ask questions such as what will be the impact of tariff changes on industry rates of return at current capital stocks. Alternatively, we could set the rates of return exogenously and ask questions concerning the size of industries. That is, for the long-run we might argue that tariff changes will not affect rates of return[1] but will affect the sizes of industries as represented by their capital stocks. This particular approach to long-run modelling will be discussed further when we consider the snapshot approach in the next section.

1. Support for this view is provided by the fact that there appears to be no relationship between rates of return to the capital of an industry and the industry's level of tariff protection. See Industries Assistance Commission [1974, Tables 3.4.1 and 4.2.3].

2. STRATEGIES FOR LONG-RUN SIMULATIONS

2.1 Accumulation through time

This is conceptually the most obvious approach, but from a practical point of view it is the hardest to implement. In terms of the ORANI model we proceed as follows . First we compute

$$\begin{pmatrix} \overset{*}{z}_1(t) \\ k(t+1) \end{pmatrix} = B(t) \begin{pmatrix} \overset{*}{z}_2(t) \\ k(t) \end{pmatrix} \qquad (2.1)$$

where $\begin{pmatrix} \overset{*}{z}_1(t) \\ k_1(t+1) \end{pmatrix}$ is the vector of endogenous variables and was previously denoted by $z_1(t)$. $\begin{pmatrix} \overset{*}{z}_2(t) \\ k(t) \end{pmatrix}$ is the vector of exogenous variables, previously denoted by $z_2(t)$, and $B(t)$ is the elasticities matrix, previously denoted by $-A_1^{-1} A_2$. In the new notation, $k(t)$ is the vector of percentage changes in current capital stocks and $k_1(t+1)$ is the vector of percentage changes in future capital stocks, i.e., capital stocks existing at time $t+1$. Normally, $k(t)$ would be set exogenously at zero -- changes in tariffs, etc. do not affect current capital stocks. However, they do affect investment plans and therefore they do change future capital stocks from the levels which they would have reached in the absence of the tariff changes. $k(t+1)$ is to be interpreted as the percentage deviations of capital stocks existing at time $t+1$ from the levels they would have reached if the exogenous changes, $\overset{*}{z}_2(t)$ had not taken place. In other words, $k(t+1)$ is the vector of percentage changes in the capital stocks of time $t+1$ attributable to the exogenous changes, $\overset{*}{z}_2(t)$, at time t . Notice that we are treating the capital

Alaouze, [1976], Alaouze, Marsden and Zeitsch [1977], and the data base supporting the estimates is explained in Marsden and Milkovits [1977].

(ii) We do not adopt the small country assumption on the export side. For the main exports, ORANI includes a non-infinite elasticity of foreign demand for Australian commodities.

(iii) For the agricultural industries we have incorporated results from the CRESH-CRETH study.[1] With CRESH-CRETH we recognize both the joint nature of agricultural enterprises and regional differences in their production functions. Agricultural output from each region is limited by the availability of land. In addition, diversification of output within the regions is modelled. Under the CRESH-CRETH system we view the typical farmer's production decision in two parts. First the farmer buys inputs (e.g., labour, capital, fertilizers, etc.) to apply to his fixed factor, land. Given the inputs, the farmer then has a choice of possible combinations of outputs (wheat, sheep, cattle, etc.). The production possibilities are described by a transformation frontier exhibiting less than infinite elasticities of transformation.[2]

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1. The relevant papers are Dixon, Powell and Vincent [1976] and Vincent, Dixon and Powell [1977, 1978].

2. Antecedents of our work on agriculture include Powell and Gruen [1968] and Hasenkamp [1976].

3.2 Fixed factors in every industry

The second approach to avoiding flip-flop problems is to have a fixed factor in every industry. This has been a popular strategy in general equilibrium models of international trade. Normally it takes the form of declaring industry capital stocks non-shiftable and exogenous.[1] Certainly, for short-run analysis, the adoption of fixed capital stocks is reasonable. In the long-run, however, capital is mobile. Consequently, in models which rely on fixed capital stocks as the diversifying device, long-run analysis is usually restricted to the indicator approach outlined in section 2.3

3.3 Modelling the long-run diversifying phenomena

The third approach to the elimination of flip-flop is clearly ideal : one should attempt to identify the real world diversifying factors and include them in the model. For ORANI, we have made the following progress in this direction.

(i) Domestically produced goods and their competitive imports are treated as separate commodities which are substitutes (but not perfect substitutes) in each use.[2] The estimation of the relevant substitution elasticities is described by

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1. Examples of models employing the non-shiftability assumption are Taylor and Black [1974], Klijn [1974], Staelin [1976] and of course ORANI in short-run mode.

2. Our work in this area was heavily influenced by Armington [1969, 1970] and Artus and Rhomberg [1973].

stocks of time t+1 as an endogenous variable for time t . At time t+1 , these capital stocks will become predetermined.

In short-run mode equation (2.1) is as far as we go. The $z_1^*(t)$ vector shows the percentage changes in the endgenous variables arising as a result of the exogenous changes, $z_2^*(t)$, over a period of time in which we can ignore the impact of z_2^* on capital stocks and the subsequent further impact on z_1^* . The situation is illustrated in figure 1.

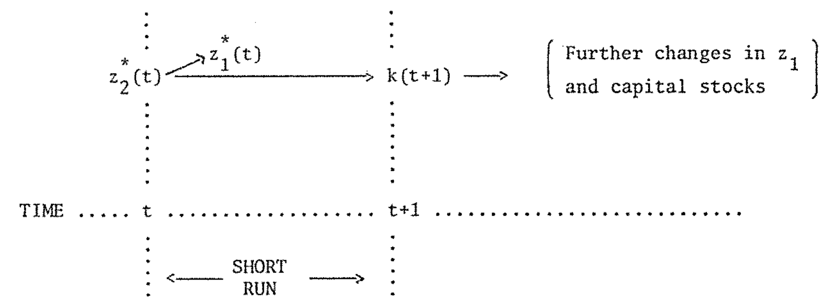

Figure 1

The timing in figure 1 is left, purposely, a little vague. One possible story is that time occurs in discrete instances. At instant t we introduce the shock $z_2^*(t)$ and produce the response $z_1^*(t)$. The response $z_1^*(t)$ includes changes in investment plans.

However, the new investment plans have no impact on capital stocks until time $(t+1)$. At that instant, capital stocks differ by the percentages $k(t+1)$ from the levels they would have reached if the initial shock $z_2^*(t)$ had not taken place. This story is, perhaps, unnecessarily stark. Hopefully, however, readers will find it helpful in interpreting our subsequent discussion.

While $z_1^*(t)$ may be adequate for short-run analysis, for the long-run we need to consider the effects of the changes, $k(t+1)$, in capital stocks. We do this by computing

$$\begin{pmatrix} z_1^*(t+1) \\ k(t+2) \end{pmatrix} = B(t+1) \begin{pmatrix} z_2^*(t) \\ k(t+1) \end{pmatrix} . \tag{2.2}$$

The right hand side implies that the exogenous variables at time $t+1$ differ from the values which they would have had in the absence of the initial shock by the percentages $\begin{pmatrix} z_2^*(t) \\ k(t+1) \end{pmatrix}$.[1] As a result, at time $t+1$, the endogenous variables, including the capital stocks of time $t+2$, differ from the values they would have had by the vector $\begin{pmatrix} z_1^*(t+1) \\ k(t+2) \end{pmatrix}$. In general we have

$$\begin{pmatrix} z_1^*(t+\tau) \\ k(t+\tau+1) \end{pmatrix} = B(t+\tau) \begin{pmatrix} z_2^*(t) \\ k(t+\tau) \end{pmatrix} \tag{2.3}$$

1. In (2.2) we assume that the initial shock is sustained, i.e., the z_2^* variables at time $t+1$ continue to differ by $z_2^*(t)$ from the values they would have had in the absence of the initial shock.

3.1 Exogenization of international trade

Exogenization of international trade can take several forms. For example, in the SNAPSHOT model,[1] exports are set exogenously and imports are restricted to being no more than exogenously specified shares of the domestic market. In Evans, we find minimum output constraints and maximum export limits, i.e., to avoid the flip-flop problem, he ensured that domestic producers occupied a reasonable share of the domestic market for each commodity by including constraints of the form

$$X \geq X_{min} \tag{3.1}$$

where X is the vector of domestic outputs and X_{min} is an exogenously given vector of minimum plausible output levels. Evans also forced diversification of the export vector by introducing the constraints

$$E \leq E_{max} \tag{3.2}$$

where E is the vector of export levels and E_{max} is an exogenously given vector of maximum plausible levels.

Shadow prices on constraints such as (3.1) and (3.2) can be helpful in an analysis of questions concerning international trade. However, it is obvious that a model in which the setting of trade flows is largely exogenous is far from ideal for the analysis of the impact of tariff changes, changes in world commodity prices, etc.

1. See Dixon, Harrower and Powell [1976] and Dixon, Harrower and Vincent [1978].

The underlying reason for flip-flop behaviour is a failure to model sufficient of the real-world phenomena which explain industrial diversification. For example, in a review[1] of Evans [1972], it was pointed out that (without various arbitrary constraints) the model produced unconvincing patterns of industrial specialization because of, among other things, its omission of

(a) terms of trade effects. Evans adopted the small country assumption. In particular, exports of any commodity could be expanded to any extent without lowering prices.

(b) diminishing returns. All production in the Evans model is with constant returns to scale. There are no industries in which growth is restricted by non-producible factors such as land and scarce mineral resources.

(c) differences in the properties of imported and domestically produced goods of the same name. In the Evans model, imported and domestic chemicals, say, are perfect substitutes in all uses. Thus the model shows a tendency to imply that the economy will either rely completely on imports for a particular commodity or completely on domestic production.

Approaches to overcoming the flip-flop problem can be classified under three headings :

(i) exogenization of international trade ,

(ii) the introduction of a fixed factor in every industry ,

(iii) the modelling of long-run diversifying phenomena .

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1. See Dixon and Butlin [1977].

and we use $z_1^*(t+\tau)$, where τ is large, as our indicator of the long-run effects of the initial shock $z_2^*(t)$.

In writing equations (2.1), (2.2) and (2.3), we have included a time argument on the elasticities matrix B. Readers who are familiar with the ORANI model (or other models in the Johansen class) will recall that the elements of the A matrix (see equation 1.1) are made up from cost shares and sales shares as well as various substitution elasticities. For example, a typical ORANI equation is of the form

$$x_j - \sum_i \beta_{ij} x_{ij} = 0$$

where the variables are x_j , the percentage change in the output of good j , and x_{ij} , the percentage change in the demand for good j by user i . The parameters are the β's where β_{ij} is the share of the total sales of j that go to user i . In forming the A matrix (and therefore the B matrix), the β_{ij} are treated as constants. However, cost shares and sales will vary in an identifiable way under the influence of the shock $z_2^*(t)$. Hence, ideally, as we move from equation (2.1) to (2.2) to (2.3), we should update the cost and sales shares.

Assume first however that we ignore the changes in sales and cost shares, i.e., we assume

$$B(t+\tau) = B \quad \text{for all} \quad \tau \geq 0 \quad ,$$

then our computations proceed by substituting for $k(t+\tau)$ in terms of

$\overset{*}{z}_2(t)$. Assuming that $k(t) = 0$ we have

$$\left.\begin{aligned} \overset{*}{z}_1(t) &= B_{11}\overset{*}{z}_2(t) \\ k(t+1) &= B_{21}\overset{*}{z}_2(t) \end{aligned}\right\} \quad (2.1a)$$

$$\left.\begin{aligned} \overset{*}{z}_1(t+1) &= B_{11}\overset{*}{z}_2(t) + B_{12}k(t+1) \\ &= \left(B_{11} + B_{12}B_{21}\right)\overset{*}{z}_2(t) \\ k(t+2) &= B_{21}\overset{*}{z}_2(t) + B_{22}k(t+1) \\ &= \left(B_{21} + B_{22}B_{21}\right)\overset{*}{z}_2(t) \end{aligned}\right\} \quad (2.2a)$$

$$\vdots$$

$$\left.\begin{aligned} \overset{*}{z}_1(t+\tau) &= B_{11}\overset{*}{z}_2(t) + B_{12}k(t+\tau) \\ &= \left(B_{11} + B_{12}\left(I + B_{22} + B_{22}^2 + \ldots + B_{22}^{\tau-1}\right)B_{21}\right)\overset{*}{z}_2(t) \end{aligned}\right\} \quad (2.3a)$$

when the B_{rs} are submatrices of B .

Provided that the series $I+B_{22}+B_{22}^2 + \ldots$ converges,[1] then we can write

$$\lim_{\tau\to\infty}\left(\overset{*}{z}_1(t+\tau)\right) \equiv \overset{*}{z}_1(LR) = \left\{B_{11}+B_{12}\,(I-B_{22})^{-1}\,B_{21}\right\}\overset{*}{z}_2(t)$$

1. This will happen if and only if all the eigenvalues of B_{22} are of modulus less than one.

We have then relied on the short-run results for industry outputs, investment and rates of return to indicate the likely long-run incidence of tariff and other changes. Our assumption has been that there is a high correlation between the short impact of a change (e.g., a tariff reduction) and the eventual long effects; that industries which win in the short-run as indicated by what happens to their rates of return are also the industries which win in the long-run in terms of improved growth prospects.

3. SPECIALIZATION PROBLEMS AND FOREIGN TRADE

A common difficulty with long-run modelling exercises which emphasize international trade is overspecialization. To date, the ORANI model has suffered to some extent from this problem and this explains our reluctance to report genuine long-run computations.

The overspecialization problem is well-known from the linear programming literature where it is often described by the words "flip-flop" or "knife-edge".[1] Models suffering from "flip-flop" exhibit unrealistically specialized patterns of industrial output. Typical results show very few goods being exported, and those which are exported are exported in vast quantities. On the import side, there is a tendency for demands for commodities to be satisfied entirely by imports with domestic production at zero, or alternatively, for imports to be zero and for domestic production to account for 100 per cent of domestic sales.

1. For a general discussion of the problem, see Taylor [1975, section 4].

i.e., the 25 per cent tariff cut. Notice that by including $\kappa(t+\tau)$ on the exogenous list, we are assuming that the tariff cut does not affect the economy's overall level of capital accumulation.[1] It does, however, affect the distribution of capital across industries. Consequently, the levels of current capital stocks (i.e., the levels at time $t+\tau$) are endogenous. What we are assuming is that over the long-run, i.e., the period between t and $t+\tau$, the distribution of capital stocks across industries adjusts so as to eliminate the changes in relative rates of return induced by the initial shock. In the long-run, capital is mobile.

2.3 The short-run indicator of long-run consequences

For reasons which will become apparent in the next section, rather severe limitations have been required on the currently operational version of ORANI in order to produce believable long-run results under either of the approaches discussed in subsections 2.1 and 2.2. In some or our applications papers where we have been concerned with long-run issues, we have in fact preferred to operate the model in short-run mode, i.e., we have used equation (2.1) with the current capital stocks on the exogenous list.[2]

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1. Alternatively, we could leave $\kappa(t+\tau)$ on the endogenous list and exogenize the absolute, rather than the relative, rates of return. This would be an attractive strategy in a model incorporating a satisfactory theory of foreign capital flows. In such a model, we could think of capital inflows and outflows as playing the role of determining long-run rates of return in Australia. At its present stage of development, ORANI does not include an explicit theory of capital flows.

2. Dixon, Parmenter and Sutton [1978a] is an example.

where $z_1^*(LR)$ is our vector of long-run percentage changes in the endogenous variables resulting from the shock $z_2^*(t)$. We say that in the long-run endogenous variables will differ by the percentages $z_1^*(LR)$ from the values they would have had if there had been no shock $z_2^*(t)$.

On the other hand if we include the time subscript on the B matrix and carry out the updating procedure for each period we obtain

$$\left.\begin{aligned} z_1^*(t) &= B_{11}(t)z_2^*(t) \\ k(t+1) &= B_{21}(t)z_2^*(t) \end{aligned}\right\} \qquad (2.1b)$$

$$\left.\begin{aligned} z_1^*(t+1) &= B_{11}(t+1)z_2^*(t) + B_{12}(t+1)k(t+1) \\ &= \left\{B_{11}(t+1) + B_{12}(t+1)B_{21}(t)\right\}z_2^*(t) \\ k(t+2) &= B_{21}(t+1)z_2^*(t) + B_{22}(t+1)k(t+1) \\ &= \left\{B_{21}(t+1) + B_{22}(t+1)B_{21}(t)\right\}z_2^*(t) \end{aligned}\right\} \qquad (2.2b)$$

$$\vdots$$

$$z_1^*(t+\tau) = $$

$$\left\{\begin{aligned} B_{11}(t+\tau) &+ B_{12}(t+\tau)B_{21}(t+\tau-1) \\ &+ B_{12}(t+\tau)B_{22}(t+\tau-1)B_{21}(t+\tau-2) \\ &+ B_{12}(t+\tau)B_{22}(t+\tau-1)B_{22}(t+\tau-2)B_{21}(t+\tau-3) \\ &+ \vdots \\ &+ B_{12}(t+\tau)B_{22}(t+\tau-1) \;\ldots\ldots\ldots\ldots\; B_{21}(t) \end{aligned}\right\} z_2^*(t) \qquad (2.3b)$$

2.2 The snapshot approach

The snapshot device has been commonly used in programming models.[1] Its distinguishing feature is that no attempt is made to move out into the future by accumulating changes. Rather, we get there in one step. In the programming models we simply build a picture of a typical year, say five years into the future. In a model where the variables are in change form, we build a picture which tells us how outputs, employment, etc. in a typical year, say five years into the future, will differ, as the result of a current policy (or other) change, from the levels they would have reached in the absence of the policy change.

With the ORANI model, snapshot computations have been made[2] using the equation

$$\begin{pmatrix} z_1^{**}(t+\tau) \\ k(t+\tau+1) \\ k(t+\tau) \end{pmatrix} = B(t+\tau) \begin{pmatrix} z_2^{**}(t) \\ rr(t+\tau) \\ \kappa(t+\tau) \end{pmatrix} \qquad (2.4)$$

where t is the point of time at which the policy change is introduced[3] and $t+\tau$ refers to our long-run future point of time. It should be emphasised that the computations are for values of variables at time $t+\tau$: the results refer to changes in the values of variables from the level at which they would have been at time $t+\tau$. They do <u>not</u> refer to

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1. See for example Sandee [1960], Manne 1963, Evans [1972] and Dixon, Harrower and Vincent [1978]. A non-programming model of the snapshot type is described by Barker [1976].

2. See Dixon, Harrower and Powell [1977].

3. As in (2.2) we assume that the initial shock is sustained, i.e., the z_2^{**} variables at time $t+\tau$ continue to differ by $z_2^{**}(t)$ from the values they would have had in the absence of the initial shock.

changes between time t and time $t+\tau$. Two further points should be noted. First, we have rewritten the exogenous and endogenous vectors to show that current (i.e., current at time $t+\tau$) capital stocks are among the endogenous variables, while the exogenous variables include relative rates of return[1] for each industry, $rr(t+\tau)$, and a variable, $\kappa(t+\tau)$, measuring the percentage change in the economy's total capital stock.[2] Compared with equation (2.1), in equation (2.4) we have moved n variables, the current capital stocks, on to the endogenous side and replaced them on the exogenous side by the n variables, $rr(t+\tau)$, $\kappa(t+\tau)$. The second point concerns the elasticities matrix $B(t+\tau)$. This differs from that in equation (2.1) because it involves a different allocation of the columns of A between A_1 and A_2 . It may also reflect an update of A to take account of long-run changes in cost and sales shares.

Usually, we would use (2.4) as follows. We would set $\kappa(t+\tau)$ and $rr(t+\tau)$ at zero. $z_2^{**}(t)$ might be set to reflect a 25 per cent reduction in all tariffs. Then $z_1^{**}(t+\tau)$ would be interpreted as showing the percentage changes in outputs, employment, etc. which would arise at a point of time, $t+\tau$, sufficiently far into the future such that relative rates of return no longer reflect the initial disturbance,

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1. The absolute rates of return remain endogenous. We have in the model the equations

$$absr_i(t+\tau) = absr_1(t+\tau) + rr_i(t+\tau) \quad , \quad i=2,\ldots,n \ .$$

In equation (2.4), the percentage changes in the absolute rates of return, $absr_i(t+\tau)$, $i=1,\ldots,n$, appear as part of the endogenous vector $z_1^{**}(t+\tau)$. The $n-1$ relative rates of return, $rr_i(t+\tau)$, $i=2,\ldots,n$, are set exogenously. The choice of industry one's rate of return as the yardstick for measuring relative rates of return is, of course, abitrary. It has no significance for the simulation results.

2. The model includes an equation of the form

$$\kappa(t+\tau) = \sum_i S_i \ k_i(t+\tau)$$

where S_i is the share of industry i in the economy's total capital stock.