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FORECASTING VERSUS POLICY ANALYSIS WITH THE ORANI MODEL

by

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1. Introduction

ORANI is a detailed general equilibrium model of the Australian economy.[1] It has been applied many times by economists in universities, government departments and business in analyses of the effects on industries, occupational groups and regions of changes in policy variables (e.g., taxes and subsidies) and in other aspects of the economic environment (e.g., world commodity prices). These applications have been comparative static, i.e, they have been concerned with questions of how different the economy would be with and without the changes under investigation. They have not been concerned with forecasting the future state of the economy.

More recently we have experimented with the model for forecasting. In a pilot exercise (Dixon, 1986), ORANI was used to forecast growth rates of industry outputs in Australia for the period 1985-1990. This revealed some problems inherent in the use of computable general equilibrium models for forecasting.

In section 2, we describe the difference between comparative static analysis and forecasting, in general terms, and with specific reference to the ORANI model. We also discuss some computational difficulties which arise in applying ORANI to forecasting. In section 3 we present some numerical examples to supplement the theoretical material in section 2. Finally, section 4 contains some brief concluding comments on the strengths and limitations of ORANI as a forecasting device.

2. The Difference between Comparative Statics and Forecasting

The difference between comparative static analysis and forecasting is illustrated in Figure 1. This depicts two paths for the variable V_1 , derived from an economic model. The control path, AB , shows what would happen in the absence of a policy change under consideration while the shocked path, AC , shows what would happen if the policy change were implemented. Comparative static analysis is concerned with the gap between C and B . This gap measures the effect of the policy change after t years. In forecasting, on the other hand, we are concerned with whether variable V_1 is going to reach point C or point B or some other point. That is, the focus is on the gap between C or B and A.

In the context of policy questions, the most appropriate model-based input is often a comparative static analysis. However, there are other situations in which this is not adequate. Businessmen, for example, require forecasts of industry outputs, employment and other variables to assist them to make investment decisions. With a view to meeting some of their requirements, the Institute of

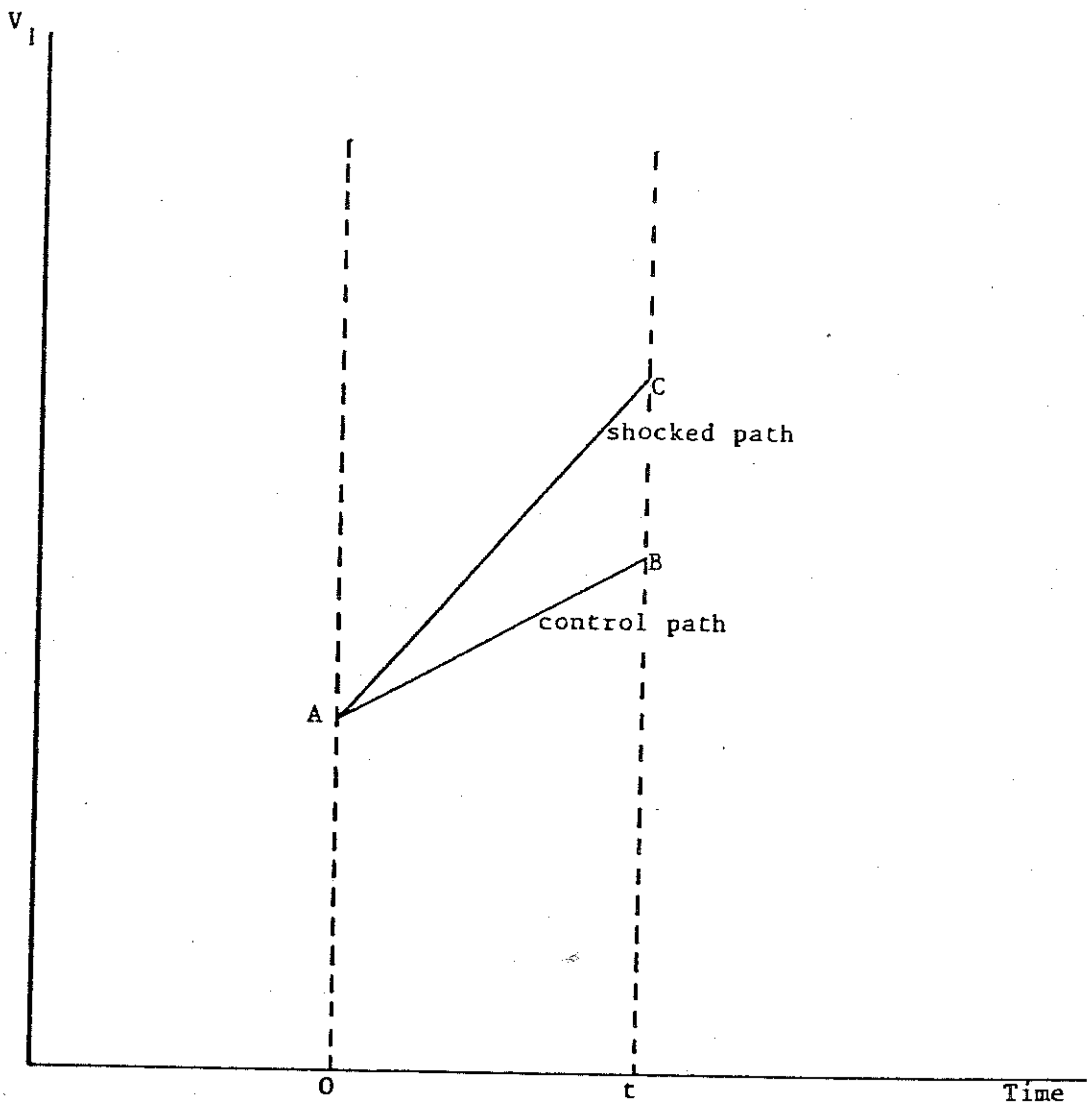

Figure 1 The Difference between Comparative Statics and Forecasting

Applied Economic and Social Research is currently devoting resources to the application of the ORANI model to forecasting.

For comparative statics, a version of the model containing no dynamic mechanisms is sufficient. This can be represented as

$$V_1(t) = g(V_2(t)) , \qquad (1)$$

where

g is the solution function relating the vector of endogenous variables at time t ($V_1(t)$) to the exogenous variables at time t ($V_2(t)$).

In comparative static exercises with this model, we compare two values of $V_1(t)$, the control value, $V_1^C(t)$ (e.g., point B in Figure 1), and the shocked value, $V_1^S(t)$ (e.g., point C in Figure 1). Results are of the form

$$\begin{aligned} C(V_2^C(t),S) &= V_1^S(t) - V_1^C(t) \\ &= g(V_2^C(t) + S) - g(V_2^C(t)) , \qquad (2) \end{aligned}$$

where

$C(V_2^C(t),S)$ is the vector of effects on the endogenous variables at time t of deviating the exogenous variables by the vector S from their control vector, $V_2^C(t)$.

Equation (2) involves no dynamic considerations. However, Figure 1 suggests that dynamic considerations might be involved in the generation of a control solution $(V_1^C(t), V_2^C(t))$. The figure indicates that the control state of the economy (represented by the point B) has evolved from its current state (point A).

To date in comparative-static exercises we have not paid much attention to the characteristics of the control solution. Because of delays in the publication of economic statistics, especially input-output tables, it is very difficult to obtain a picture of even the current state of the economy at the level of detail required by ORANI. Usually the data bases for such models refer to some period in recent history.[2] We have generally assumed that the historical data or a simple scaling up of them are adequate control solutions for comparative-static exercises. These procedures may not however provide a plausible forecast of the state of the economy for a future year t in the absence of the policy shocks to be analysed. Experience with sensitivity analyses (e.g., Dixon, Parmenter and Rimmer, 1986; Bruce, 1985) indicates that the comparative-static results are not very sensitive to details of the control solution. Intuitively, the question is whether the effects of a tariff reform (say) in the Australian economy of the late 1970's are likely to be very different from the effects of a tariff reform in the Australian economy of the late 1980's.

In contrast, for forecasting, considerably more care must be taken in generating control solutions. The reason is that forecasts explicitly entail comparisons between states of the economy at different points in time (usually the present and some future period). The inclusion of some dynamic mechanisms is, therefore, inevitable. Forecasting versions of ORANI with which we are experimenting can be represented as:

$$V_1(t) = f(V_2(t), Z(0), t) , \tag{3}$$

where

$Z(0)$ is a sub-vector of variables at time 0 , and

f is the solution function relating to the endogenous variables at time t $(V_1(t))$ to the exogenous variables at time t $(V_2(t))$ and to the initial conditions represented by $Z(0)$.

From (3), we see that forecasting versions of ORANI contain only very limited dynamic mechanisms. The values of endogenous variables at time t are explained purely by the values of exogenous variables at time t and by the values of variables at time 0 . The dynamic mechanisms which are included are capital-accumulation relationships.[3] A simplified form of these is[4]

$$K(t) = K(0) + \int_{s=0}^{t} I(s)ds \tag{4}$$

and

$$I(s) = I(0)e^{i(t)s} , \tag{5}$$

where

$K(t)$ and $K(0)$ are capital stocks at times t and 0 respectively ,

$I(t)$ and $I(0)$ are investment at times t and 0 , and

$i(t)$ is average annual rate of growth of investment over the period 0 to t .

It is the assumption that investment grows smoothly at the rate $i(t)$ that allows us to simplify dramatically the dynamics of our model. It avoids the necessity of explicitly including any variables relating to periods between 0 and t . On substituting (5) into (4) we obtain

$$K(t) = K(0) + I(0)\left(\frac{e^{i(t)t} - 1}{i(t)}\right), \text{ if } i(t) \neq 0$$

$$= K(0) + I(0)t, \qquad \text{if } i(t) = 0. \tag{6}$$

Using (3) in forecasting, we compare one value of the endogenous vector at time t (our forecast value, $V_1^F(t)$) with the initial value of this vector, $V_1(0)$. Results of forecasting exercises are usually reported as growth rates for the period 0 to t calculated as simple transformations of the vector

$$F(t, V_2^C(t)+G, V(0)) = V_1^F(t) - V_1(0)$$

$$= [V_1^F(t) - V_1^C(t)] + [V_1^C(t) - V_1(0)]$$

$$= [f(V_2^C(t) + G, Z(0), t) - f(V_2^C(t), Z(0), t)]$$

$$+ [f(V_2^C(t), Z(0), t) - V_1(0)], \tag{7}$$

where

G is the vector of deviations that we expect (forecast) in the exogenous variables over the period 0 to t away from their control values, $V_2^C(t)$.

In applying (7) we must supply observations on the initial values of variables ($V_1(0)$ and $Z(0)$) and a scenario for the exogenous variables in period t ($V_2^C(t)+G$). The second line of (7) suggests a convenient decomposition of the forecast vector (F) into:

(i) the difference between the forecast values of the endogenous variables at time t ($V_1^F(t)$) and their control values at time t ($V_1^C(t)$)

and

(ii) the difference between the control values at time t and the initial values $(V_1(0))$.

Note that the first part of this decomposition is a purely comparative-static computation, i.e., it involves a comparison between alternative values of variables at the same point in time, namely period t. The dynamic aspects of our forecasts are thus confined to the second part of the decomposition, i.e., to the computation of a valid control solution for the model for time t.

In our pilot forecasting exercise (Dixon, 1986), we assumed that the control values for the exogenous variables were the initial values, and that the second term in our decomposition was zero. These were also the assumptions implicit in the theoretical discussion by Parmenter and Meagher (1985). Underlying this approach is the false assumption that if $V_2^C(t) = V_2(0)$, then $V_1^C(t) = V_1(0)$. We should expect, however, that with $V_2^C(t) = V_2(0)$,

$$V_1(0) \neq V_1^C(t) = f(V_2(0), Z(0), t) \quad , \quad t > 0 \quad . \qquad (8)$$

Even in the absence of changes in the exogenous variables, year t will differ from year 0 because of capital accumulation. This is obvious in equations (5) and (6). If $I(0) > 0$ and we set $I(t) = I(0)$, then we find from (5) that $i(t) = 0$. By substituting into (6), we obtain $K(t) > K(0)$ for $t > 0$. In other words, if $I(0) > 0$ it is impossible to have

$$(K(t), I(t), i(t)) = (K(0), I(0), i(0)) \quad . \qquad (9)$$

More generally, the initial conditions, represented as $Z(0)$ in equation (3), will normally rule out the possibility of a stationary state. Not only are the initial values of the variables usually an implausible representation of any hypothetical state of the economy in a future year t but for the dynamic forecasting model (3) (although not for the static model (1)) they do not usually constitute a valid solution for year t.

In principle, it is straightforward to calculate a legitimate value for $V_1^C(t)$ via (8). The forecast can then be completed by computing the first term in the decomposition in (7) setting G according to forecasts of differences between the exogenous variables at time t and their values at time 0. In practice, however, evaluation of the control solution is complicated because in performing calculations with ORANI we adopt linear approximations, i.e., we do not have explicit forms for the functions g or f.

For example, in performing the computations required in evaluating the right hand side of (2) and the first term on the right hand side of (7) we adopt approximations of the form

$$g(V_2^C(t)+S) - g(V_2^C(t)) = B(V^C(t))\, S \tag{10}$$

and

$$f(V_2^C(t)+G,Z(0),t) - f(V_2^C(t),Z(0),t) = D(V^C(t),Z(0),t)\, G , \tag{11}$$

where

> B and D are matrices of partial derivatives of g and f with respect to the exogenous variables (V_2), evaluated at the points $(V^C(t))$ and $(V^C(t), Z(0), t)$ respectively.

Note that computations (10) and (11) require a valid control solution around which to perform the linearization. The matrices B and D are computed as functions of both the endogenous and exogenous variables $(V^C(t) = (V_1^C(t), V_2^C(t))$ where the $V^C(t)$ satisfy (1) or (3).

The reasons for adopting these approximations are explained in DPSV (1982, especially section 8) and Dixon (1985). Here we simply note that

(i) the approximations have proved satisfactory in a wide range of ORANI applications ,

(ii) the matrices B and D are easily evaluated from input output data and econometric estimates of substitution elasticities ,

(iii) the forms of g and f are underivable in any practical way so that (2) and (7) are not directly usable in computations ,

(iv) in the rare cases in which the approximations in (10) and (11) are inadequate, more accurate solutions are available, although with considerably increased computational difficulty. The approach which we have taken in these cases is to compute the effects of the entire shock (e.g., S in (10) or G in (11)) in a series of linear computations of the effects of smaller shocks. Between each pair of such computations the matrix of partial derivatives is reevaulated using data updated to include the effects of previous shocks. For example, instead of using (11) we might compute the effects of the shock G via n computations in each of which a shock of size G/n is imposed. First we compute

$$\Delta V_1^1(t) = D(V^C(t), Z(0), t)(G/n) ,$$

then

$$\Delta V_1^2(t) = D(V_1^C(t) + \Delta V_1^1(t),\ V_2^C(t) + G/n,\ Z(0),\ t)(G/n),$$

etc.. Details of the multi-step procedure are given in DPSV (1982, ch. 5 and section 47) . For ORANI it is shown that a 2-step solution combined with an extrapolation rule produces values for the endogenous variables very close to exact, non-linear solutions.

We have now devised a method of deriving a valid control solution $(V^C(t))$ for the forecasting model in year t which has two essential properties:

(i) it continues to rely primarily on linear approximations such as (10) and (11), i.e., it does not require an explicit form for underivable components of the function f ; and

(ii) it allows us, if necessary, still to employ the multi-step solution method for making computations free of linearization errors.

Our method is based on the observation that we can separate the model into two components, namely, the accumulation equations and the rest, the latter being a strictly static system. Hence, a valid control solution to the model can be represented as

$$K^C(t) = f^{**}(I^C(t),\ Z(0),\ t)\ , \tag{12a}$$

$$V_1^C(t) = f^*(\tilde{V}_2^C(t),\ \ K^C(t),\ \ \tilde{I}^C(t))\ . \tag{12b}$$

Note that in (12b), both the capital stock at time t $(K(t))$ and investment at time t $(I(t))$ are treated as exogenous variables. $\tilde{V}_2^C(t)$ is defined as the vector of control values of exogenous variables excluding $K(t)$ and $I(t)$. It remains true that it is impractical to derive an explicit form for f^* .[5] This is not the case for f^{**} , however. By postulating a control value for $I(t)$

and given the initial conditions $(Z(0))$ we can easily derive a valid control solution for $K(t)$ using (12a). We can then use an approximation to (12b) to compute control values for the endogenous variables $V_1(t)$ using the previously calculated control values for $K(t)$ and $I(t)$, and using initial values for the control values of the remaining exogenous variables, $\tilde{V}_2(t)$. That is, we compute

$$\Delta V_1(t) \equiv V_1^C(t) - V_1(0) , \tag{13}$$

via

$$\Delta V_1(t) = f^*(\tilde{V}_2(0), K^C(t), I^C(t)) - f^*(\tilde{V}_2(0), K(0), I(0))$$

$$= D^*(V(0))\begin{bmatrix} 0 \\ \Delta K(t) \\ \Delta I(t) \end{bmatrix} , \tag{14}$$

where D^* is the matrix of partial derivatives of f^* with respect to the exogenous variables $\tilde{V}_2$, K and I. $\Delta K(t)$ and $\Delta I(t)$ are deviations of the control values of these variables (obtained via (12a)) from their initial values. Note that D^* is evaluated at the initial values of <u>all</u> the variables. Because f^* is strictly static, i.e., it excludes the accumulation relationships, $V^C(t) = V(0)$ is a valid control solution to f^* for any period t.[6] Finally, we use the solution to (14) to update the initial values of the endogenous variables, yielding

$$V_1^C(t) = V_1(0) + \Delta V_1(t) . \tag{15}$$

Equations (14) and (15) give only an approximation to the control values of $V_1(t)$ which are consistent with our control values for $K(t)$ and $I(t)$ (and $\tilde{V}_2(t)$). However, if more accuracy is required the multi-step solution method outlined on p.10 (point (iv)) can be applied.

To summarize, we have described a two-part method for deriving a valid control solution to our entire forecasting model for period t . The solution is

$$V^C(t) = (V_1^C(t), \bar{V}_2(0), K^C(t), I^C(t)) ,$$

where $K^C(t)$ and $I^C(t)$ are calculated directly from (12a) and $V_1^C(t)$ is computed from (14) and (15). Note that the solution to (14) and (15) is closely related to the second term in our decomposition of the forecasting equation (7).[7]

We can now use (11) to compute the first term in the decomposition of (7). Moreover, in making this calculation there is nothing to stop us reassigning variables between the exogenous and endogenous sets. Our method for evaluating $V^c(t)$ involved a computation (14) in which $K(t)$ and $I(t)$ were exogenous, although one of these variables can be thought of as endogenized by (12a). In solving (11), however, we would usually include both $K(t)$ and $I(t)$ as endogenous variables. The inclusion of the accumulation relationship in f is sufficient to endogenize one of these variables. The other would usually be replaced on the exogenous list by the rates of return on capital, about which an exogenous forecast would be made.

The only outstanding problems in implementing (11) concern the shock vector, G . In forecasting, in contrast to pure comparative static exercises, considerable effort must be devoted to forecasting the exogenous variables. In the forecasting exercise reported by Dixon (1986) the setting of G involved:

(i) the consideration of data on tariff and quota changes for the period 1967 to 1983 and the assessment of announced government intentions concerning protection for steel, textiles, clothing, footwear and automobiles over the next five years ;

(ii) the consideration of data on world price movements for the period 1967 to 1983 and the assessment of how future price trends are likely to differ from past trends in view of likely changes in energy markets ;

(iii) the use of input-output calculations applied to price projections to forecast world-wide technological change by industry, and the assessment of how technological developments in Australian industries are likely to deviate from world-wide experience ;

(iv) the projection of the size of the labour force and the number of households to 1990 ;

(v) the assessment of likely changes between 1985 and 1990 in the extent of excess capacity in different Australian industries; and

(vi) the assessment of likely future changes in the cost of capital to Australian businessmen.

In formulating our vector G of forecast changes in the exogenous variables, we must be careful to deviate from the control values of these variables. Similarly, in interpreting the changes in the endogenous variables projected by (11) we must recognize that they are deviations from their control values, not their initial values.

3. A Numerical Example

A very simple model for numerical illustration of our forecasting procedure is the capital-accumulation equation (6) combined with

$$Q(t) = K(t) + I(t) . \tag{16}$$

We can interpret (16) as explaining aggregate employment (Q(t)). At time t, one unit of labour is employed in conjunction with each unit of capital for current production and one unit is employed per unit of capital creation. However, the interpretation of (16) is not important, nor is its exact form. For our purpose, the role of (16) is to represent the rest of ORANI, i.e., the non-accumulation relationships, f^*. Note that (16) is purely static, i.e., choosing $Q(t)$ as the endogenous variable, it has the same form as (12b). Equation (6) on, the other hand, has the form of (12a).

We first transform the equations to distinguish the average annual rates of growth of the variables over the period 0 to t. We define all growth rates as in (5) and rewrite (16) and (6) as[8]

$$e^{q(t)t} = \frac{K(0)}{Q(0)} e^{k(t)t} + \frac{I(0)}{Q(0)} e^{i(t)t} \tag{16'}$$

and

$$\begin{aligned} e^{k(t)t} &= 1 + \frac{I(0)}{K(0)} \left(\frac{e^{i(t)t} - 1}{i(t)}\right), \quad i(t) \neq 0 \\ &= 1 + \frac{I(0)}{K(0)} t , \qquad\qquad\qquad i(t) = 0 . \end{aligned} \tag{6'}$$

Hypothetical base-period data for the model are:

$$(K(0), I(0), Q(0)) = (100, 4, 104) . \tag{17}$$

Note that these data satisfy (16) for $t = 0$.

Imagine that we wish to use (16)' and (6)' to make forecasts of the average annual rates of growth of employment, capital and investment over a five-year period. The first task is to find a valid control solution for year 5. A "no-change" scenario

$$(\bar{q}(5),\ \bar{k}(5),\ \bar{i}(5)) \;=\; (0,\ 0,\ 0)\ , \tag{18}$$

would satisfy (16)' but not (6)'. Our procedure is to solve (6)' directly for a valid control. Two obvious choices are

(i) "no change" in investment

$$(k(5),\ i(5)) \;=\; (0.0365,\ 0.0)\ , \tag{19}$$

(ii) "balanced growth"

$$(k(5),\ i(5)) \;=\; (0.04,\ 0.04)\ . \tag{20}$$

As we shall see, our solutions are not very sensitive to the choice between (i) and (ii). To complete the control solution we require a value $q(5)$ compatible with our chosen controls $k(5)$ and $i(5)$. In deriving this we assume that (16)' is unavailable. Instead we must use a first-order linear approximation to it, the linearization being performed around the no-change values of the variables (18). The linearized equation is

$$q(t) - \bar{q}(t) \;=\; \left[\frac{K(0)e^{\bar{k}(t)t}}{Q(0)e^{\bar{q}(t)t}}\ ,\ \frac{I(0)e^{\bar{i}(t)t}}{Q(0)e^{\bar{q}(t)t}}\right]\begin{bmatrix} k(t) - \bar{k}(t) \\ i(t) - \bar{i}(t) \end{bmatrix}\ . \tag{21}$$

Equation (21) is analagous to (14), with the qualification that our example is in terms of changes in the average rates of change of the variables, not changes in their levels. Using (17) and (18), (21) reduces to

$$q(5) \;=\; (0.9615,\ 0.0385)\begin{pmatrix} k(5) \\ i(5) \end{pmatrix}\ , \tag{22}$$

which yields

$$\begin{aligned} q(5) &= 0.0351\ , \text{ given (19)} \\ &= 0.04\ \ \ \ \ , \text{ given (20)}\ . \end{aligned}$$

Hence, we have derived two alternative valid control solutions for (16)' and (6)'. They are

$$(\bar{q}(5), \bar{k}(5), \bar{i}(5)) = (0.0351, 0.0365, 0.0) \tag{23}$$

and

$$(\bar{q}(5), \bar{k}(5), \bar{i}(5)) = (0.04, 0.04, 0.04) . \tag{24}$$

These are valid control solutions in the sense that, given the initial conditions (17) they satisfy (16') and (6)' simultaneously.

To complete our forecast we require a first-order linear approximation to the entire model (16)' and (6)', evaluated at one of our valid control solutions. Linearizing (6)' we obtain

$$(te^{\bar{k}(t)t})(k(t)-\bar{k}(t)) = \gamma(i(t)-\bar{i}(t)) , \tag{25}$$

where

$$\begin{aligned} \gamma &= \frac{I(0)}{K(0)}\left[\frac{e^{\bar{i}(t)t}\ (\bar{i}(t)t-1) + 1}{\bar{i}(t)^2}\right], \quad \bar{i}(t)=0 \\ &= \frac{t^2 I(0)}{2\ K(0)} , \qquad\qquad \bar{i}(t)=0 . \end{aligned} \tag{26}$$

Combining (21) and (25), the complete linear system is

$$\begin{bmatrix} 1 , & -\dfrac{K(0)e^{\bar{k}(t)t}}{Q(0)e^{\bar{q}(t)t}} , & -\dfrac{I(0)e^{\bar{i}(t)t}}{Q(0)e^{\bar{q}(t)t}} \\ 0 , & te^{\bar{k}(t)t} , & -\gamma \end{bmatrix} \begin{bmatrix} q(t) - \bar{q}(t) \\ k(t) - \bar{k}(t) \\ i(t) - \bar{i}(t) \end{bmatrix} = 0 . \tag{27}$$

We use equation (27) to compute the comparative static component of our forecast. Evaluating (27) at one of our valid control solutions (say (24)), using initial conditions (17),[9] gives

$$\begin{bmatrix} 1, & -0.9615, & -0.0385 \\ 0, & 6.1070, & -0.5719 \end{bmatrix} \begin{bmatrix} q(5) - 0.04 \\ k(5) - 0.04 \\ i(5) - 0.04 \end{bmatrix} = 0 . \tag{28}$$

Assume that $q(t)$ is the exogenous variable, then, from (28)

$$\begin{bmatrix} k(5) - 0.04 \\ i(5) - 0.04 \end{bmatrix} = - \begin{bmatrix} -0.9615, & -0.0385 \\ 6.1070, & -0.5716 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ 0 \end{bmatrix} \begin{bmatrix} q(5) - 0.04 \end{bmatrix} , \tag{29}$$

or

$$\binom{k(5)}{i(5)} = \binom{0.04}{0.04} + \binom{0.7285}{7.7796} \left(q(5) - 0.04\right) . \tag{30}$$

Next, assume that our exogenous forecast of $q(5)$ is 0.05, then via (30) our forecasts for $k(5)$ and $i(5)$ are

$$\binom{k(5)}{i(5)} = \binom{0.0473}{0.1180} .$$

These values are listed in Table 1 together with forecasts derived by solving (16)' and (6)' directly and via (27) using (23) and (18) as control solutions.

The first row of the table gives exact solutions generated by solving (16)' and (6)' directly. Note that answers derived from multi-step solution of (27) (fifth row) reproduce the exact solutions without error. Single-step solutions of (27) using either of our valid control solutions (second and third rows) produce accceptable approximations to the exact solutions. Use of (27) under the false assumption that no change in all variables is a valid control solution for year 5 (fourth row) does not yield an acceptable approximation.

Table 1 Alternative forecasts of k(5) and i(5) given q(5) = 0.05

Forecasts	Endogenous variables k(5)	i(5)
Via exact solution of (16)' and (6)'	0.047	0.109
Via single-step solutions of (27)		
Evaluated at (23): investment constant in control solution	0.048	0.132
Evaluated at (24): balanced growth control solution	0.047	0.118
Evaluated at (18): invalid "no change" control solution	0.035	0.427
Via multi-step solution of (27) evaluated at (24): balanced growth control solution	0.047	0.109

4. Concluding Remarks

The strength of general equilibrium models is their ability to handle inter-industry linkages. Industries are linked through input-output relationships and also through their competition in factor markets. The importance of these linkages has long been recognized in policy analysis. For example, when we consider the effects of increases in tariffs we must account for cost increases flowing from sectors receiving greater protection to other sectors, particularly export sectors, via inter-industry transactions and labour markets. It is not surprising, therefore, that frequent use is made in policy debates of comparative static simulations from general equilibrium models.

Our experience with the ORANI model suggests that inter-industry linkages are also of vital importance in forecasting. For example, in Dixon (1986), our exogenous scenario included slow growth in foreign demand for Australian agricultural products. Via the ORANI model we derived forecasts of slow growth in agricultural outputs. The model also indicated that growth in the mining sector would be rapid. This is because a poor performance in agriculture will improve competitive conditions for our mineral sector by leading to a deterioration in our real exchange rate. Thus, in forecasting prospects for the mining sector it was necessary to consider carefully prospects for other sectors of the economy.

Although general equilibrium models have much to offer as forecasting devices, their potential cannot be realized fully without considerable effort. As we saw in section 2, the workload involved in a general equilibrium forecast is much greater than that required for a comparative static calculation. Unlike the situation in comparative statics, in forecasting we must make a detailed assessment of the likely future course of a large number of exogenous variables.

Another problem which increases the workload in forecasting relative to that in comparative statics is delays in the collection and publication of statistics. For example, input-output tables which are the main data input for general equilibrium models, are available for Australia from the Australian Bureau of Statistics only up to 1979. If we are trying to forecast industry growth rates from 1985 to 1990 then it is clearly of importance to know the details of the situation in 1985, particularly for industries such as construction and agriculture which are subject to strong cyclical or climatic influences. For example, if we failed to recognize that capital creation was unusually high in 1985, then we would be in danger of over-estimating growth prospects for construction industries to 1990. In terms of equation (27), up-to-date information on the state of the economy is required in the evaluation of $I(0)/K(0)$. If this is set too low, then our forecast growth rate for investment, $i(t)$, is likely to be too high. This suggests that despite difficulties associated with publication lags, the data bases of general equilibrium models should be updated before these models are used in forecasting.

In section 2, we saw that forecasting with ORANI requires a slightly different computational approach from that used in comparative statics. This is because of difficulties in generating a valid control solution for year t. Fortunately, it appears that the computational problems associated with forecasting can be overcome without significant disturbance to the ORANI computing codes. This can be done by (a) generating a control solution for ORANI's accumulation relationships in their non-linear form and (b) using this solution as exogenous shocks in a linear computation of control values for variables not included in the accumulation equations.

Finally, it is worth mentioning two issues which traditionally are of central interest to forecasters : validation and dynamics. As with most general equilibrium models, ORANI has not been subjected to detailed validation. One of the advantages of adapting the model to forecasting applications is that validation will then be possible. The Institute is currently undertaking a project in which the performance of the model in tracking developments of the 1970's will be assessed.

In comparison to other forecasting techniques, e.g., Box-Jenkins methods, in the general equilibrium approach comparatively little attention is given to dynamics. This is a problem not only in forecasting but also in comparative statics. The nature of the difficulty can be seen by examination of either equation (2) or (7). In these equations it is not clear at what time the shocks S and G are applied. Normally in comparative statics we assume that the shock S is applied at time zero and is sustained up to time t. In forecasting we often assume that the shock G develops smoothly over the period zero to t. It should be emphasized, however, that the theoretical structure of a general equilibrium model provides no guidance as to the appropriate interpretation of the evolution of the exogenous shock.

In work at the IMPACT Project, Cooper, McLaren and Powell[10] have made a substantial contribution to overcoming the dynamic limitations of general equilibrium models. They have shown how given paths for exogenous shocks over the period zero to t can be aggregated into the appropriate shocks S and G in equations (2) and (7) to be applied in a comparative static computation for time t. In forming S and G, their method gives greater weight to shocks occuring early in the period zero to t, rather than later. Shocks (e.g., tariff changes) occuring close to t have little time in which to influence outputs, prices, employment, etc.. It is likely that adoption of Cooper, McLaren and Powell's methods will lead to substantial improvements in both the forecasting and comparative static capabilities of the ORANI model.

End Notes

1. The model, which is fully described in Dixon, Parmenter, Sutton and Vincent (1982), hereafter DPSV (1982), was developed at the IMPACT Project. IMPACT is a joint research endeavour of several agencies of the Australian government in collaboration with the University of Melbourne, La Trobe University and the Australian National University. It has been directed since its inception in 1975 by Alan A. Powell, Ritchie Professor of Research in Economics at the University of Melbourne. For a recent overview of the Project, see Powell (1985). For an overview of ORANI applications, see Parmenter and Meagher (1985). Parmenter and Meagher also provide useful comments on forecasting versus policy analysis.

2. The current ORANI data base refers to 1977-78 but contains data on the agricultural sector averaged over a number of years. Hence, the data contain a representation of agriculture which is typical of recent history.

3. Earlier versions of ORANI, including that described in DPSV (1982), had no explicit accumulation relationships. The most authoritative paper on these relationships in ORANI is Horridge (1985).

4. In (4) and (5) we ignore depreciation, we fail to append industry subscripts and we make no distinction between foreign and domestic ownership of capital stocks. While these complications are included in ORANI, see Horridge (1985) and Dixon, Parmenter and Rimmer (1984), they are not essential at this stage.

5. The function f^* in our forecasting version of ORANI is very similar to the function g in our comparative-static version.

6. Control solutions to f^* are thus exactly analagous to control solutions for g in model (1).

7. The difference is that the variables treated as endogenous in (14) may not coincide precisely with the list of endogenous variables in the complete forecast. Nevertheless, the solutions to (14), (15) and (12a) contain all the information necessary to construct the second term in (7).

8. The conversion to growth-rate form is the "simple transformation" of the forecast vector referred to on p.7.

9. Note that the coefficients in the first row of (27) could also be written as

$$\left[1, \frac{K^C(t)}{Q^C(t)}, \frac{I^C(t)}{Q^C(t)}\right] .$$

This form makes it apparent that the coefficients can be calculated from updated data. For example, when (24) is used the control data is

$$(Q^C(t), K^C(t), I^C(t)) = (127.03, 122.14, 4.89) .$$

10. See, for example, Cooper and McLaren (1983) and Cooper, McLaren and Powell (1985).

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