Impact Project

Impact Centre
The University of Melbourne
153 Barry Street, Carlton
Vic. 3053 Australia
Phones: (03) 341 7417/8
Telex: AA 35185 UNIMEL
Telegrams: UNIMELB, Parkville

IMPACT is an economic and demographic research project conducted by Commonwealth Government agencies in association with the Faculty of Economics and Commerce at The University of Melbourne and the School of Economics at La Trobe University

THE LONG TERM EFFECTS OF IMPROVED LABOUR PRODUCTIVITY IN THE AUSTRALIAN BASIC IRON AND STEEL INDUSTRY

by

Russell J. Rimmer
La Trobe University

Preliminary Working Paper No. OP-47 Melbourne May 1984

The views expressed in this paper do not necessarily reflect the opinions of the participating agencies, nor of the Commonwealth Government

ISBN 0 642 52514 5

CONTENTS

LIST OF FIGURES AND TABLES

Figure

Table

30. (cont.)

$$\sigma_{(g+1,1)63}\,[p_{(g+1,1)63} - S^*_{(g+1,1)63}\,p_{(g+1,1)63} - (1 - S^*_{(g+1,1)63})\,p_{(g+1,2)63}]$$

$$= \sigma_{(g+1,1)63}\,(1 - S^*_{(g+1,1)63})\,[p_{(g+1,1)63} - p_{(g+1,2)63}] \,.$$

With the values given for $\sigma_{(g+1,1)63}$ and $S^*_{(g+1,1)63}$ in sub-section 2.1, the last expression becomes

$$0.299\,[p_{(g+1,1)63} - p_{(g+1,2)63}] \,.$$

In the long-run environment adopted here labour is assumed to be fully employed, while the capital stock in each industry is allowed to adjust to exogenous shocks. As a result of the labour-augmenting technical change in the basic iron and steel sector there is an increase in the industry wage rate (projected to be $p_{(g+1,1)63} = 1.01\%$) relative to the rental price for a unit of capital in the industry (projected to be $p_{(g+1,2)63} = 0.54\%$). Thus the effect on employment of labour in the sector is:

$$0.299[1.01 - 0.54] = 0.14\% \,.$$

31. Note that while the ORANI theory allows for CRESH technology on the input side and CRETH technology on the product side (see DPSV, Chapter 3), in the present version only three agricultural industries are modelled as having CRETH transformation prospects.

32. See Vincent (1980), pp.45-46.

33. SNAPSHOT is a programming model of the Australian economy. The economy is viewed as if it maximizes an objective function subject to a set of production possibilities, a balance of payments constraint and additional constraints ensuring adequate diversification of investment and employment across sectors, satisfactory income distribution, etc. See Dixon and Vincent (1980) for a description of the SNAPSHOT model.

25. (cont.)

$$x_{(g+1,1,6)j} = z_j + \text{occupational specific and primary factor substitution term} + \delta_{63,j} \text{ (technical change term)},$$

where $\delta_{63,j} = 1$ if $j = 63$ and 0 otherwise. For this analysis, assume that

$$x_{(g+1,1,6)18} \approx z_{18}$$

and

$$x_{(g+1,1,6)j} \approx 0 \quad \text{for } j \neq 18.$$

Then, (6) becomes

$$\ell_6 \approx B_{(g+1,1,6)18}\, z_{18}.$$

As $B_{(g+1,1,6)18} = 0.188$, and $z_{18} = -2.71$ (recorded in Table 4.2, row 9), an approximation to ℓ_6 is given by:

$$\ell_6 \approx 0.188 \times (-2.71)$$
$$= -0.51 .$$

This is close to the value reported in Table 4.1 for the percentage change in employment of the occupational group skilled blue collar (other).

26. Projections for employment by industry can be obtained from ORANI.

27. See DPSV, p.307.

28. See DPSV, pp.340-341.

29. In the ORANI long-run simulation the iron mining industry's supply schedule is horizontal (see section 5). However, for convenience these schedules are shown as non-horizontal in Figures 4.1 and 4.2.

30. Equation (2.7b) describes the demand for labour in the basic iron and steel industry, and within this equation the term describing the effect of changes in factor prices is:

$$\sigma_{(g+1,1)63} \, (p_{(g+1,1)63} - \sum_{\ell=1}^{3} S^*_{(g+1,\ell)63}\, p_{(g+1,\ell)63}) .$$

But in the current implementation of ORANI industry 63 is assumed not to use land in its production process, so that this expression may be simplified to

THE LONG TERM EFFECTS OF IMPROVED LABOUR PRODUCTIVITY IN THE AUSTRALIAN BASIC IRON AND STEEL INDUSTRY

by

Russell J. Rimmer*

1. INTRODUCTION

The Australian government has recently announced a five year assistance package for the iron and steel producer Broken Hill Proprietary Ltd. (BHP) based on bounties paid to steel users. While the assistance package operates BHP will endeavour to reduce its production costs and regain its competitiveness in world markets. Both unions and management have agreed that to achieve this aim an annual productivity level of 250 tonnes of iron and steel per employee must be established in major steel works. According to industry estimates for the whole of 1983 this is a productivity increase of 22% or 45 tonnes per employee. The company expects to realise this gain through natural workforce attrition and by reducing the level of trainees in the steelworks from 15% to 10% (which is the normal level). Once this initial productivity goal has been attained the unions involved have agreed to a rate of productivity growth for BHP 2% faster than the national average, which traditionally runs at about 2%. This, plus a planned investment catch-up on prior years of low spending, will bring worker productivity in BHP steel mills within 5 years into line with the productivity levels currently obtained by Japanese steel workers.[1]

This paper attempts to quantify the long term effects of the initial 22% projected productivity growth on industry output levels, employment by occupation, aggregate real wages, real domestic absorption[2] aggregate exports, aggregate imports and the aggregate capital stocks. To simulate the responses of these indicators the ORANI model of the Australian economy will be used in long-run mode.[3] Hagan and Smith (1980) used an earlier version of the ORANI model to simulate the inter-industry effects of labour-saving technical change. ORANI is a multisectoral model distinguishing 113 industries and including a facility for imposing technical change either neutral or augmenting of specific inputs. In section 2 the relevant parts of the ORANI production theory and the implementation of technical change are reviewed. As the emphasis of this study is on the long-term implications of technical change, section 3 is devoted to discussion of the use of ORANI in long-run mode. The results of the ORANI simulation of a labour-augmenting technical change in the production of basic iron and steel are presented in section 4. Finally, in section 5 two problems with the ORANI long-run facility are discussed, and conclusions are offered.

23. (cont.)

$$x = K/X(\partial f/\partial K)\ k + N/X(\partial f/\partial N)\ n + L_0/X(\partial f/\partial L_0)\ \ell_0$$

$$+ Q/X(\partial f/\partial X)\ (\ell_{63} - a_{(g+1,1)63}) \ . \qquad (4)$$

For details of the next step the interested reader is referred to P.B. Dixon, S. Bowles and D. Kendrick, Notes and Problems in Microeconomic Theory, 1980 (Amsterdam: North Holland), pp.224-226. Provided that factor rentals are equated with their marginal products and that the aggregate production function (1) is homogenous of degree 1 then, by taking as numeraire the price of a unit of aggregate output, (4) may be rewritten as:

$$x = S_k K + S_N n + S_0 \ell_0 + S_{63}\ell_{63} - S_{63}\ a_{(g+1,1)63}\ , \qquad (5)$$

where

$$S_K + S_N + S_0 + S_{63} = 1,$$

and S_K, S_N, S_0 and S_{63} may be interpreted as factor shares in aggregate output. The expression $S_0\ell_0 + S_{63}\ell_{63}$ appearing in (5) may be written as $S_L\ \ell$ so that equation (5) may be converted into (4.2) by using this result and by equating gdp with x.

24. This adjustment mechanism is analogous to that advanced by Gregory (1976) and Dixon, Parmenter and Sutton (1978b).

25. To see this note that, ℓ_6, the percentage change in employment of the skilled blue collar (other) occupation is given by DPSV, Table 23.1 as:

$$\ell_6 = \sum_{j=1}^{h} B_{(g+1,1,6)j}\ x_{(g+1,1,6)j}\ , \qquad (6)$$

where $B_{(g+1,1,6)j}$ is the share of the economy wide employment in occupation 6 which is accounted for by industry j, and $x_{(g+1,1,6)j}$ is the percentage change in employment of occupation 6 by industry j. The ORANI equation for $x_{(g+1,1,6)j}$ is given in (2.5). By substituting (2.6a) into (2.5) the equation for $x_{(g+1,1,6)j}$ becomes:

23. To derive (4.2) assume that the aggregate production function for the economy is given by:

$$X\ (K,N,L_0,L_{63}/A_{(g+1,1)63}), \qquad (1)$$

where:

L_0 = economy wide employment level except for labour employed in industry 63,

L_{63} = employment level in industry 63,

$A_{(g+1,1)63}$ = technology coefficient for the usage of labour in industry 63, and

K and N are the economy-wide usages of capital and land, respectively.

With $Q = L_{63}/A_{(g+1,1)63}$ a small increment ΔX in X may be approximated from (1) by:

$$\Delta X = (\partial f/\partial K)\Delta K + (\partial f/\partial N)\Delta N + (\partial f/\partial L_0)\Delta L_0 + (\partial f/\partial Q)\Delta Q\ ,$$

so that

$$x = 100\ \Delta X/X$$

$$= (K(\partial f/\partial K)k + N(\partial f/\partial N)n + L_0(\partial f/\partial L_0)\ell_0 + (\partial f/\partial Q)\Delta Q)/X, \quad (2)$$

where k, n and ℓ_0 denote percentage changes in K, N and L_0 respectively, and ΔQ may be written as:

$$\Delta Q = (\partial Q/\partial L_{63})\ \Delta L_{63} + \Delta A_{(g+1,1)63}\ (\partial Q/\partial A_{(g+1,1)63})$$

$$= \Delta L_{63}/A_{(g+1,1)63} - \Delta A_{(g+1,1)63}\ (L_{63}/A^2_{(g+1,1)63})$$

$$= (\ell_{63} - a_{(g+1,1)63})\ L_{63}/A_{(g+1,1)63}$$

$$= (\ell_{63} - a_{(g+1,1)63})\ Q\ . \qquad (3)$$

Eliminate ΔQ from (2) using (3) to obtain

2. THE EFFECTS OF LABOUR-AUGMENTING TECHNICAL CHANGE IN THE ORANI PRODUCTION THEORY.

A labour-augmenting technical change has the following consequences in the industry in which it occurs:

(i) less labour is required to produce each unit of output, but as labour has become more efficient producers will substitute labour for some fixed capital inputs;

and

(ii) if intermediate input prices and factor rentals are fixed then the production cost of a unit of output would fall in this industry.

These are referred to as the direct effects of the technical change.

In sub-sections 2.1 and 2.2 the ORANI theory is used to explain the direct effects in more detail.

2.1 The ORANI industry input technology and labour-augmenting technical change.

At any given level of activity ORANI assumes that producers in industry j purchase the combination of inputs which minimizes costs. Also, producers are assumed to be competitive in that they regard all input and output prices as exogenously given. The production technology incorporated into ORANI is fully analyzed in Dixon, Parmenter, Sutton and Vincent (hereafter DPSV) (1982, sub-section 11.1). Here the formation of a unit of activity in industry j, denoted Z_j, is summarized in Figure 2.1.[4] The figure shows all possible inputs to current production that can be purchased by each of the h ORANI industries.[5] These consist of 2g commodities (g domestically produced and g imported), M occupational categories of labour,[6] industry fixed capital and land inputs, and inputs of other cost tickets.[7] The ORANI production functions depicted in Figure 2.1 are of a three level nested form, and exhibit constant returns to scale. At level 3 effective units of labour are constructed as CRESH[8] composites of labour from the M different occupational groups. At level 2 effective units of material input i are defined as CES[9] combinations of domestic and imported supplies of the i^{th} commodity classification, and effective units of primary factors are constructed as CRESH combinations of capital, agricultural land and effective inputs of labour. A technological change in the overall use of labour can be introduced at this point. Finally, at level 1 a given level of activity in industry j is generated using, in fixed proportions, effective units of produced inputs, effective units of primary factors, and inputs of other costs.

The Leontieff technology used to combine inputs at level 1 in Figure 2.1, precludes the possibility of substitution between effective units of primary factors and effective inputs of produced commodities or other costs as a result of relative price movements between these groups. Solution of each producer's cost minimization problem using the technological constraints shown in Figure 2.1 can be carried out in stages. For example, at levels 2 and 3 industry j will choose the

13. The percentage reduction in total primary factor input costs to basic iron and steel production, denoted by c, is given by:

$$c = \alpha S_{(g+1,1)63} + \beta S_{(g+1,2)63},$$

where α and β are the reductions in demands for inputs of labour and fixed capital, respectively, by industry 63 for a fixed level of activity and with constant primary factor rentals. In the text α and β are computed using

$$\alpha = a_{g+1,1)63} [1 - \sigma_{(g+1,1)63} (1 - S_{(g+1,1)63})]$$

and $$\beta = a_{(g+1,1)63}\, \sigma_{(g+1,1)63}\, S_{(g+1,1)63} .$$

Using the fact that $S_{(g+1,2)63} = 1 - S_{(g+1,1)63}$ it can be shown that c is given by

$$c = a_{(g+1,1)63}\, S_{(g+1,1)63} ,$$

and so when $a_{(g+1,1)63} = -22$ the reduction in primary factor costs in basic iron and steel production is:

$$c = -22(0.766)$$
$$= -16.85\%.$$

14. See DPSV, Section 18, pp. 108-110.

15. The basic value of each domestically produced good is the price received by the producer.

16. The balance of trade may pass through zero, and so this variable appears in the model in change form (rather than percentage change form).

17. See DPSV, Section 50, pp. 344-353.

18. See Cooper (1983).

19. See Parmenter (1981), p. 3.

20. See Dixon, Parmenter and Sutton (1978a), pp. 6-11.

21. See DPSV, pp. 143-144.

22. See Dixon, Parmenter and Rimmer (1983).

ENDNOTES

* An earlier draft of this paper was submitted as part fulfillment of the requirements for the author's M.Ec. preliminary qualification at La Trobe University. The author is indebted to Brian Parmenter, for his encouragement and advice during the preparation of the paper, and to Tony Meagher who read and commented on an earlier draft.

1. See Australian Financial Review, Fri, Aug.12, 1983, p.1 and p.8.

2. Domestic absorption is defined as the sum of aggregate consumption, aggregate investment and government spending.

3. The model is described fully in Dixon. P.B., B.R. Parmenter, J. Sutton and D.P. Vincent (1982), referred to as DPSV.

4. Figure 2.1 is derived from Higgs, P.J., D. Parham and B.R. Parmenter (1981).

5. In the current version of ORANI h = 113.

6. In the current version of ORANI, g = 115 and M = 9.

7. "Other costs" include costs of working capital and production taxes.

8. CRESH (constant ratio of elasticities of substitution, homothetic) functions were introduced by Hanoch (1971). See DPSV, pp. 70-72 for an introduction to the use of CRESH production functions in the ORANI theory.

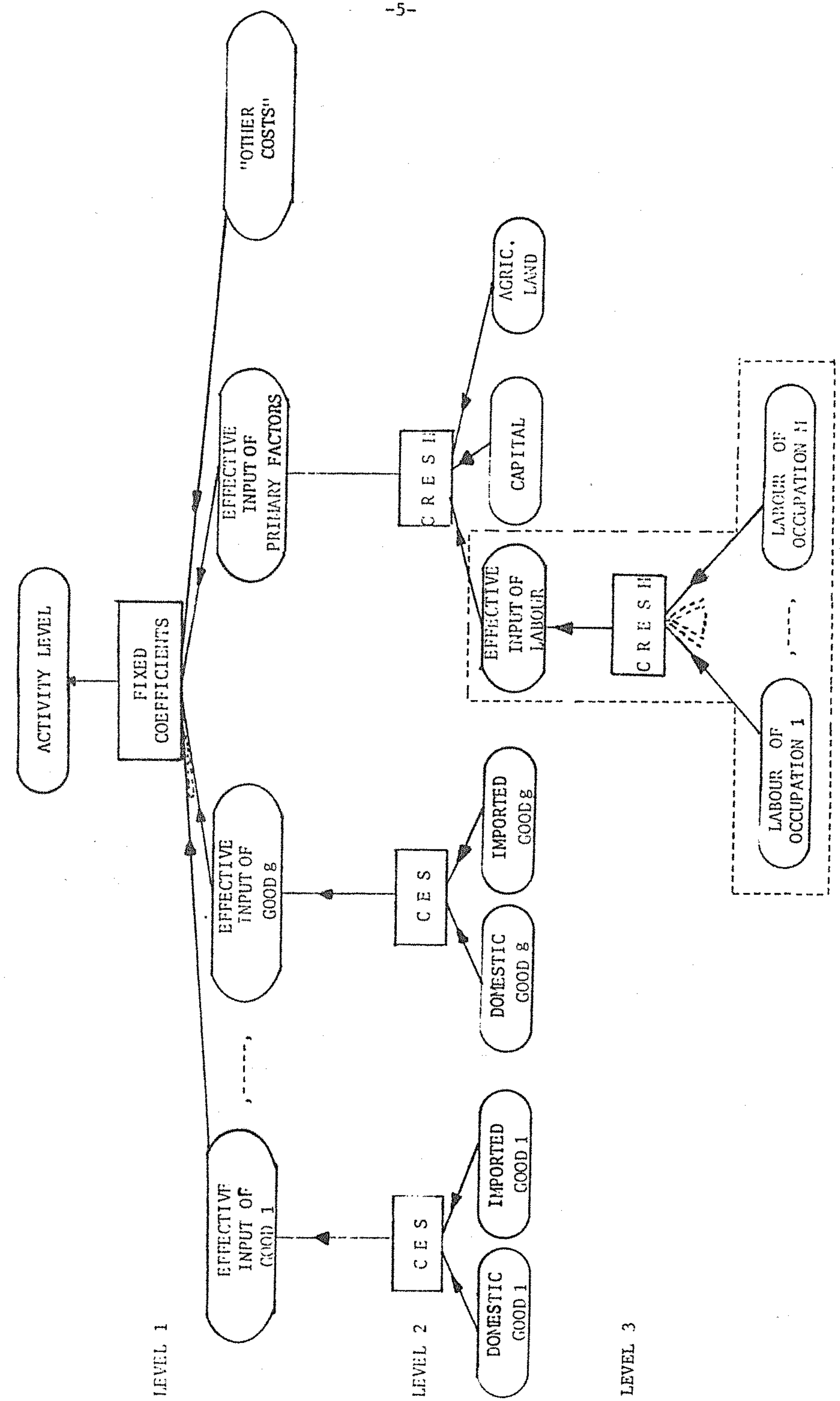
9. CES (constant elasticity of substitution) functions were first applied by Arrow et al. (1961).

10. See DPSV, pp. 83-89 for the details of the derivation of the primary factor demand equations which are numbered (12.56), (12.64) and (12.66). In general the notation useed by DPSV is adopted here, except that when no ambiguity will arise in this paper superscripts are omitted.

11. In the current implementation of ORANI only 7 agriculture activities use land as an input to production, so that equation (2.8) for v=3 applies only to industries 1 to 7.

12. When $x_{(g+1,1)63}$ is eliminated from (2.5) using (2.6a) then the 15.42% reduction in demand for labour in general translates into a 15.42% reduction in demand for labour of each skill type if the activity level and occupational wage relativities are fixed.

Figure 2.1. Input technology for current production in ORANI



combination of capital, land and labour of each occupational type to minimize the costs of providing the effective input of primary factors required to sustain any given activity level.

In percentage change form the complete solution for the cost minimizing selection of primary factors is given by the following equations:[10]

$$x_{(g+1,1,q)j} = x_{(g+1,1)j} - \sigma_{(g+1,1,q)j}\Big(p_{(g+1,1,q)j} - \sum_{\ell=1}^{M} S^{*}_{(g+1,1,\ell)j}\, p_{(g+1,1,\ell)j}\Big)$$

$$+ a_{(g+1,1,q)j} - \sigma_{(g+1,1,q)j}\Big(a_{(g+1,1,q)j} - \sum_{\ell=1}^{M} S^{*}_{(g+1,1,\ell)j}\, a_{(g+1,1,\ell)j}\Big)$$

$$q=1,2,\ldots M,\ j=1,2,\ldots,h \qquad (2.1)$$

$$x_{(g+1,v)j} = z_j - \sigma_{(g+1,v)j}\Big(p_{(g+1,v)j} - \sum_{t=1}^{3} S^{*}_{(g+1,t)j}\, p_{(g+1,t)j}\Big)$$

$$+ a_{(g+1,v)j} - \sigma_{(g+1,v)j}\Big(a_{(g+1,v)j} - \sum_{t=1}^{3} S^{*}_{(g+1,t)j}\, a_{(g+1,t)j}\Big)$$

$$+ a_j \quad + a_{g+1,j} \qquad v=1,2,3,\ \ j=1,2,\ldots,h \qquad (2.2)$$

$$p_{(g+1,1)j} = \sum_{q=1}^{M} p_{(g+1,1,q)j}\, S_{(g+1,1,q)j} + \sum_{q=1}^{M} a_{(g+1,1,q)j}\, S_{(g+1,1,q)j}, \qquad (2.3)$$

where all lower case arabic symbols are percentage changes in the variables indicated below:

Dixon, P.B. and D.P. Vincent (1980), "Some Economic Implications of Technical change in Australia to 1990/91: An Illustrative Application of the SNAPSHOT Model", The Economic Record, Vol. 56, No. 155, pp. 347-361.

Gregory, R.G. (1976), "Some Implications of the Growth of the Mining Sector", Australian Journal of Agricultural Economics, 20(2), pp. 71-91.

Hagan, P.J. and D.R.M. Smith (1980), "Modelling the Effects of Technological Change", a paper presented to the Ninth Conference of Economists, Brisbane, available from the Industries Assistance Commission, Canberra.

Hanoch, G. (1971), "CRESH Production Functions", Econometrica, 39, September, pp. 695-712.

Higgs, P.J., D. Parham and B.R. Parmenter (1981), "Occupational Wage Relativities and Labour-Labour Substitution in the Australian Economy: Applications of the ORANI Model", IMPACT Preliminary Working Paper, No. OP-30, pp. 45.

Horridge, J.M. and A.A. Powell (1984), "Long-Run Closure of ORANI: A Proposal", IMPACT Preliminary Working Paper, No. OP-46, pp. 92, April.

Parmenter, B.R (1981), "Long-run Simulations with ORANI: The Macroeconomic Closure Problem", IMPACT Research Memorandum, mimeo, pp. 53.

Vincent, D.P. (1980), "Some Implications for the Australian Economy of Trade Growth with Newly Industrializing Asia: The Use and Limitations of the ORANI Framework", in K. Andĕrson and A. George (eds), Australian Agriculture and Newly Industrialising Asia: Issues for Research (Canberra: Australia - Japan Research Centre), pp. 360-395.

REFERENCES

Arrow, K.J., H.B. Chenery, B.S. Minhas and R.M. Solow (1961), "Capital-Labour Substitution and Economic Efficiency", Review of Economics and Statistics, 43, August, pp. 225-250.

Australian Bureau of Statistics (1979), Australian National Accounts Input-Output Tables, 1974-75 (Catalogue No. 5208.0), Australian Government Publishing Service, Canberra.

Caddy, V. (1976), "Empirical Estimation of the Elasticity of Substitution: A Review", IMPACT Preliminary Working Paper, No. OP-09, pp. 43, November.

Caddy, V. (1977), "The Application of a Random Coefficient Model to the Problem of Estimating Aggregate Production Parameters", IMPACT Preliminary Working Paper, No. OP-10, mimeo, pp. 29, March.

Cook, L.H. and P.B. Dixon (1982), "Structural Change and Employment Prospects for Migrants in the Australian Workforce", Australian Economic Papers, Vol 21, No. 38, pp. 69-84, June.

Cooper, R.J. (1983). "A Tariff Experiment on the Interfaced ORANI-MACRO System", IMPACT Preliminary Working Paper, No. IP-18, pp. 29, April.

Dixon, P.B., B.R. Parmenter and R.J. Rimmer (1983), "Extending the ORANI Model of the Australian Economy: Adding Foreign Investment to a Miniature Version", in H.E. Scarf and J.B. Shoven, (eds), Applied General Equilibrium Analysis (New York: Cambridge University Press, forthcoming).

Dixon, P.B., B.R. Parmenter and J.M. Sutton (1978a), "Notes on the Theory of Long-Run Simulations with the ORANI Model", IMPACT Preliminary Working Paper, No. OP-20, pp. 27, July.

Dixon, P.B., B.R. Parmenter and J.Sutton (1978b), "Some Causes of Structural Maladjustment in the Australian Economy", Economic Papers, No. 57, pp. 10-26, January.

Dixon, P.B., B.R. Parmenter, J. Sutton and D.P. Vincent (1982), ORANI: A Multisectoral Model of the Australian Economy (Amsterdam: North Holland), referred to in text as DPSV.

$x_{(g+1,1,q)j}$: demand for labour of skill class q by industry j,

$x_{(g+1,v)j}$: demand for primary factor v by industry j, where v=1 corresponds to effective labour, v=2 capital and v=3 agricultural land,

z_j : the activity level of industry j,

$a_{(g+1,1,q)j}$: the technology coefficient for the employment of labour of skill q by industry j,

$a_{g+1,j}$: industry j's technology coefficient for the use of effective inputs of primary factors,

$a_{(g+1,v)j}$: industry j's technology coefficient for inputs of primary factors for v=1,2,3,

$P_{(g+1,1,q)j}$: price to industry j of a unit of labour of skill q,

$P_{(g+1,v)j}$: rental prices of primary factor v(=2,3) in industry j,

$P_{(g+1,1)j}$: price to industry j of a unit of effective labour.

The parameters are :

$\sigma_{(g+1,v)j}$: a CRESH parameter reflecting the degree of substitutability between primary factor v and other primary factors in industry j's current production process,

$\sigma_{(g+1,1,q)j}$: a CRESH parameter reflecting the degree of substitutability between labour of type q and labour of other types in the production process of industry j,

$S_{(g+1,1,q)j}$: the share of total costs of labour in industry j accounted for by occupation q,

$S^*_{(g+1,1,q)j}$: the modified occupation q cost share arising from the CRESH formation of effective labour inputs, defined as:

$$S^*_{(g+1,1,q)j} = \frac{\sigma_{(g+1,1,q)j}\, S_{(g+1,1,q)j}}{\sum_{\ell=1}^{M} \sigma_{(g+1,1,\ell)j}\, S_{(g+1,1,\ell)j}} , \qquad \text{and}$$

$S^*_{(g+1,v)j}$: the modified share of total primary factor costs in industry j accounted for by primary factor v, defined as :

$$S^*_{(g+1,v)j} = \frac{\sigma_{(g+1,v)j}\, S_{(g+1,v)j}}{\sum_{\ell=1}^{3} \sigma_{(g+1,\ell)j}\, S_{(g+1,\ell)j}} ,$$

where

$S_{(g+1,v)j}$ = share of primary factor v in the total costs of primary factors in industry j.

In ORANI simulations of the effects of exogenous technical change the "a" variables in equations (2.1) - (2.3) are set exogenously. Labour-augmenting technical change can be simulated via suitable choices of values for these variables. For example, a 1 percent occupation-q-augmenting technical change in industry j requires

$$a_{(g+1,1,q)j} = -1 ,$$

with all the other a's set to zero. For a 1 percent labour-augmenting technical change in industry j which is occupation-neutral we would set

Dixon and Vincent stress that they are drawing their conclusion from employment results based on a 9-order occupational classification (which is identical to the classification used here). By moving to a more disaggregated occupational classification of the workforce some groups may be seen to experience high levels of unemployment (indicating a need for re-training programmes for workers in those occupations), while at the same time revealing likely shortages of workers with specific skills. A method for decomposing ORANI employment projections into occupation-specific changes for 71 categories is described in Cook and Dixon (1982).

export volumes in long-run simulations) is to investigate and incorporate into ORANI features of increasing costs associated with the extraction of larger quantities of ore. Work in this area is currently underway at IMPACT.

Subject to the qualifications just mentioned, the introduction of new technology by basic iron and steel producers allows this industry to expand its level of output, and its demand for labour, over that which it would have attained in the absence of the technical change. The increased demand for labour in an environment of full employment in the snapshot year raises the economy-wide real wage rate. With the balance of trade and the nominal exchange rate both fixed, the increased activity in the basic iron and steel industry is achieved with increased inflation, and at the expense of reduced activity amongst other exporting industries and in the import-competing sector. Increases in domestic prices are generated by the growth of domestic absorption and an increasing nominal wage level. There is a redistribution of resources between the traded and non-traded sectors, which leads to the occupational changes in the workforce shown in Table 4.1.

The fluctuations in employment in the snapshot year projected by ORANI at the level of nine occupations are quite modest. This is consistent with the results of a study by Dixon and Vincent (1980) of the implications of technical change in the Australian economy to 1990/91. For their work Dixon and Vincent used the SNAPSHOT model.[33] They concluded that :

> "The overwhelming impression from Table 4.6 [of their paper] is that the occupational composition of the workforce at the 9-order level in 1990/91 is unlikely to be radically different from that in 1971/72 and that it will be determined largely independently of technical change. Certainly, the present simulations do not pinpoint any likely difficulties in the areas of labour mobility and manpower training." (See Dixon and Vincent (1980), sub-section 4.2(c)).

$$a_{(g+1,1)j} = -1,$$

again with all the other a's set to zero.

2.2 The direct effects of a 22 per cent labour-augmenting technical change in the basic iron and steel industry.

Following the theory set out in sub-section 2.1, in order to simulate occupation-neutral, labour-augmenting technical change in t[illegible]c iron and steel industry (industry number 63 in ORANI) all the variables modelling technical change are exogenous and all but one are assumed to be zero. That is, in (2.1)-(2.3)

$$\left.\begin{aligned} a_{(g+1,1,q)j} &= 0 \quad \text{for each } q \text{ and } j, \\ a_j = a_{g+1,j} &= 0 \quad \text{for each } j, \\ a_{(g+1,v)j} &= 0 \quad v=2,3 \text{ and for each } j, \\ \text{and} \quad a_{(g+1,1)j} &= 0 \quad \text{for each } j \neq 63. \end{aligned}\right\} \qquad (2.4)$$

Therefore equations (2.1)-(2.3) simplify to:

$$x_{(g+1,1,q)j} = x_{(g+1,1)j} - \sigma_{(g+1,1,q)j}\left(p_{(g+1,1,q)j} - \sum_{\ell=1}^{M} S^{*}_{(g+1,1,\ell)j}\; p_{(g+1,1,\ell)j}\right) \qquad (2.5)$$

$$x_{(g+1,1)j} = z_j - \sigma_{(g+1,1)j}\left(p_{(g+1,1)j} - \sum_{\ell=1}^{3} S^{*}_{(g+1,\ell)j}\; p_{(g+1,\ell)j}\right)$$

$$+ \; \delta_{63,j}\, a_{(g+1,1)j} \left[1 - \sigma_{(g+1,1)j}\left(1 - S^{*}_{(g+1,1)j}\right)\right] \qquad (2.6a)$$

$$x_{(g+1,v)j} = z_j - \sigma_{(g+1,v)j}\Big(p_{(g+1,v)j} - \sum_{\ell=1}^{3} S^{*}_{(g+1,\ell)j}\, p_{(g+1,\ell)j}\Big)$$

$$+ \delta_{63,j}\, \sigma_{(g+1,v)j}\, S^{*}_{(g+1,1)j}\, a_{(g+1,1)j} \qquad v=2,3 \qquad (2.6b)$$

$$p_{(g+1,1)j} = \sum_{q=1}^{M} p_{(g+1,1,q)j}\, S_{(g+1,1,q)j}, \qquad (2.7)$$

where

$$\delta_{63,j} = \begin{cases} 0 & \text{if } j \neq 63 \\ 1 & \text{if } j = 63 . \end{cases}$$

According to equation (2.5) industry j's demand for labour of skill q varies proportionately with j's demand for labour in general if occupational wage relativities do not change. But if the wage of occupation q falls relative to a weighted average of all occupational wage rates in industry j, then that industry will substitute skill group q in place of other occupations in its labour force. In (2.6a) the variable $p_{(g+1,1)j}$ is the percentage change in the costs to industry j of a unit of labour and, with $a_{(g+1,1,q)j} = 0$ for each q, this is given by (2.7) as a weighted average of the percentage changes in occupational wage rates in that industry.

Interpretation of equations (2.6a and b) is now straightforward. For the moment suppose that $a_{(g+1,1)63} = 0$. Then each industry's demands for labour in general (via (2.6a)), capital and agricultural land[11] (via (2.6b)) vary proportionately with activity in the sector provided relative factor prices in the industry do not change. Alternatively, an increase in the cost to industry j of any one factor relative to the other two, leads to substitution away from that factor.

The second problem is that in long-run mode ORANI suffers from a mild form of the overspecialization or "flip-flop" problem with respect to export-oriented activities. The elasticities of foreign demand curves for the products whose export levels are endogenous in ORANI are quite high, but are less than infinity, thus providing some restraints on the projected movements in export volumes. Nevertheless, as may be seen in Table 4.2, activity in the coal industry, for example, decreases by 9.46%. However, the pastoral zone, the wheat/sheep zone, and the high rainfall zone activities experience a much smaller contraction in activity. Two features of this current version of ORANI reduce the tendency of these three agricultural activities to overspecialize:

(i) as pointed out by Vincent (1980), the own price elasticity of output of each commodity by industry j under the ORANI CRESH-CRETH[31] production technology depends <u>inversely</u> on the share of fixed factor costs W_F^j in that industry. If W_F^j is zero then the supply curve for that industry is horizontal. In long-run simulations where labour markets are slack and capital is mobile only those industries which use land (namely, those in the agricultural sector) have non-horizontal supply schedules.[32]

(ii) the ORANI treatment of agriculture permits only limited transformation possibilities between the commodities produced by each of the pastoral, wheat/sheep, and high rainfall zones.

One line of research into the flip-flop behaviour displayed by the ORANI mining industries (which are single product activities, have no fixed-factor usage in long-run mode, and which usually show the greatest variation of

5. CONCLUSION

This paper reports on the use of the ORANI model in long-run mode to investigate some of the implications for the Australian economy of a 22% labour-augmenting technical change in the basic iron and steel industry. There are two problems with the use of ORANI in the long-run environment described in sub-section 3.3. In this environment ORANI projects the change in the size of the aggregate capital stock following the labour-augmenting technical change, but currently the model provides no basis for projecting the shares of domestic savers and foreign investors in financing this capital stock. For example, it can be seen from Table 4.1 that, given fixed rates of return to capital, the aggregate capital stock in the snapshot year would be 0.37% greater as a result of the labour-augmenting technical change than its level in the snapshot year had labour-productivity not changed. The assumption that the balance of trade remains constant (in the long-run scenario described in sub-section 3.3) implies that this increase in the aggregate capital stock is financed from domestic sources, otherwise an increased balance of trade surplus would be required to allow for additional profit repatriation.

DPSV, section 49.3.3, have suggested a means of handling this issue, which involves the addition to the ORANI model of domestic savings and aggregate investment functions for the snapshot year, equations that explain the aggregate amounts of domestic saving and capital accumulation over the snapshot period, and an equation modelling variations in the domestic ownership of capital in the snapshot year. Dixon, Parmenter and Rimmer (1983) have recently built a miniature version of ORANI which incorporates these extensions. Work is currently underway on the implementation of a similar theory for ORANI (see Horridge and Powell (1984)).

Now suppose that there is a 22% labour-augmenting technical change in the basic iron and steel sector, that is set $a_{(g+1,1)63} = -22$. Provided that the sector's activity level and relative factor prices are unchanged, industry 63 could produce a unit of output with a 22% reduction in its labour input. But because iron and steel producers are cost minimizers they will substitute labour for capital at each activity level as labour has become relatively more efficient. Therefore the resulting reduction in demand for labour by this industry will be less than 22%. In (2.6a) with j = 63 and z_{63} and $p_{(g+1,v)63}$ assumed to be zero (corresponding to the assumptions of a fixed activity level and factor rentals in the sector) the change in industry 63's demand for labour is given by :

$$x_{(g+1,1)63} = a_{(g+1,1)63} \ [1 - \sigma_{(g+1,1)63} \ (1-S^*_{(g+1,1)63})]. \qquad (2.8)$$

Multiplying out the square bracket on the RHS of (2.8) separates out the substitution term, given by $[-a_{(g+1,1)63}\sigma_{(g+1,1)63}(1-S^*_{(g+1,1)63})]$. The magnitude of the substitution effect depends on the labour substitution parameter $(\sigma_{(g+1,1)63})$ for the sector, and $S^*_{(g+1,1)63}$, the CRESH modified share of labour in the basic iron and steel industry's primary factor costs, which is also a function of the factor substitution parameters.

The potential advantage of the CRESH production technology over the CES specification is that CRESH allows the elasticity of substitution between labour and capital to differ from that between capital and land, and, in turn these may both differ from the elasticity of substitution between land and labour. When only 2 primary factors are used in the production process (as is the case for ORANI's non-agricultural industries, which use only capital and labour) there is little advantage in choosing CRESH over CES. In the case of ORANI's agricultural industries an attempt was made to estimate separate values for the 3 different substitution elasticities. This econometric work failed in that it supported the use of CES functions only. With the CES production technology specified for industry j the parameter $\sigma_{(g+1,1)j}$ is the elasticity of substitution between labour and all other primary factor inputs, and $S^*_{(g+1,1)j}$ simplifies to be the share $S_{(g+1,1)j}$ of labour in industry j's primary factor costs. Following the work of Caddy (1976), (1977) the values chosen for the primary factor substitution elasticities in each sector for the long-run simulation reported here were

$$\sigma_{(g+1,v)j} = 1.276, \qquad v = 1,2,3, \qquad j=1,2,\ldots,h.$$

This implies that the pairwise substitution elasticities between land, labour and capital in each of the land using industries is 1.276; while for those sectors which do not use land, the elasticity of substitution between capital and labour is also 1.276.

Base period data for the simulation was obtained from the Australian Bureau of Statistics (ABS) 1974-75 input-output tables for Australia. From this data, $S_{(g+1,1)63}$ was computed as:

$$S_{(g+1,1)63} = 0.766, \qquad (2.9)$$

and so a 22% labour-augmenting technical change in the basic iron and steel industry induces substitution towards labour in general of

$$1.276\ (1-0.766)\ 22.0 = 6.58\%$$

The overall reduction in demand for labour under conditions of fixed activity level and fixed factor price relativities is then -22.0 + 6.58 = -15.42%.[12]

The term involving $a_{(g+1,1)j}$ in equation (2.6b) quantifies the degree of substitution away from capital and land inputs into current production by industry j when labour becomes relatively more efficient. In our example the

This percentage change is close to the increase in activity reported in Table 4.3 for the ship and boat building industry. Expansion in the water transport sector is due to a large increase in demand for the use of water transport to facilitate the flow of intermediate inputs to basic iron and steel producers.

4.3 Employment in the basic iron and steel industry

Recall that at any given output level the labour-augmenting technical change implies that 22% less labour is required to produce a unit of output in the industry. But as labour has become more efficient iron and steel producers tend to substitute labour for capital in their manufacturing process, so that, if the level of output in the industry had been held constant at the level prior to the introduction of the technical change, and if relative factor prices had remained constant, demand for labour overall by the basic iron and steel sector would have declined by -15.42% (see sub-section 2.1). But as a result of the 22% labour-augmenting technical change in the basic iron and steel industry, activity in the sector is projected to expand by 30.40% (see Table 4.3). Therefore exclusive of the effect of changes in relative factor prices, employment in the manufacture of basic iron and steel increases by 30.40 - 15.42 = 14.98%.

In the ORANI simulation, where both relative factor prices and output in the basic iron and steel sector are allowed to fluctuate to accommodate the labour-augmenting technical change, employment in the industry is projected to grow by 14.84%. Thus the effect of also allowing the wage-rental ratio to adjust[30] to the labour-augmenting technical change, is to reduce the employment of labour in the industry by only 14.98-14.84 = 0.14%.

The first industry listed in Table 4.3, ownership of dwellings, sells only to household consumption. As the household expenditure elasticity for this commodity is 2.0, the increase in aggregate consumption (0.32%) translates into a 0.64% growth in demand for the ownership of dwellings. This percentage change is close to that given for ownership of dwellings in Table 4.3. Except in the ship and boat building industry, a component of the increased activity by each of the other sectors in Table 4.3 may be attributed to the increased level of real consumption.

The increase in activity in ship and boat building is due to expansion of both investment and output by the water transport industry. The share $I_{69,95}$ of the output of the small ship and boat building industry used by water transport operators for investment purposes in the data base is 0.36, and the share $S_{69,95}$ absorbed as an input to current production is 0.28. As a result of the labour-augmenting technical change in the basic iron and steel industry investment in the water transport sector (y_{95}) expands by 1.27%, while the industry's output level (z_{95}) grows by 0.53% . Therefore, the effect of the expansion of the water transport industry on the level of activity in the ship and boat building industry is :

$$I_{69,95}\, y_{95} + S_{69,95}\, z_{95} = 0.36(1.27) + 0.28(0.53)$$
$$= 0.61\%.$$

change in the use of fixed capital (the only non-labour factor used by industry 63) is given by

$$-22\, \sigma_{(g+1,1)63}\, S_{(g+1,1)63} = -22(1.276)\ (0.766)$$
$$= -21.49\%.$$[13]

The discussion in this section has been based on the assumption that there is no change in activity levels. Such changes are excluded from our definition of the "direct effects" of the technical change (see p.3). As will be seen in section 4 when we include the indirect or general equilibrium effects projected by ORANI, there is increased activity by basic iron and steel producers following the introduction of new technology. This influences demand for labour in general (via the appearance of z_j in (2.6a)), and is sufficiently large to translate the 15.42% reduction in demand for labour by the industry into increased demand for this factor.

One further equation in the ORANI system will be affected directly by the imposition of labour-augmenting technical change in the basic iron and steel sector. ORANI requires that there is zero pure profits in the production activities of each sector.[14] That is, the basic value[15] of the output of industry j should exactly equal its total production costs. For industry 63 this condition is given in percentage change form by :

$$p^{(0)}_{(63,1)} = \sum_{i=1}^{g} \sum_{s=1}^{2} P_{(is)63}\, H_{(is)63} + \sum_{q=1}^{M} P_{(g+1,1,q)63}\, H_{(g+1,1,q)63}$$
$$+ \sum_{s=2}^{3} P_{(g+1,s)63}\, H_{(g+1,s)63} + H_{g+2,63}\, P_{g+2,63} + a(63)\ , \qquad (2.10)$$

where once again lower case symbols denote percentage changes in ORANI variables as follows:

$P^{(0)}_{(63,1)}$: basic value of a unit of production by the basic iron and steel sector,

$P_{(is)63}$: price to the basic iron and steel producers of a unit of commodity i from source s used in current production,

a(63) : a weighted sum of the technical change terms affecting the production function for the basic iron and steel industry,

$P_{g+2,63}$: price of other cost tickets to industry 63.

$H_{(is)63}$, $H_{(g+1,v)63}$, $H_{(g+1,1,q)63}$ and $H_{g+2,63}$ are the shares of industry 63's costs accounted for by inputs of commodity i from source s, by inputs of capital (v=2) and land (v=3), by inputs of labour of skill q, and by purchases of other cost tickets.

With the assumptions made in (2.5), a(63) becomes

$$a(63) = a_{(g+1,1)63} H_{(g+1,1)63}$$
$$= -22(0.247)$$
$$= -5.43,$$

where the value of $H_{(g+1,1)63}$ (0.247) is calculated from the data base. For the moment assume that prices are held constant. So, from a state in which (2.10) is satisfied with a(63) = 0 the imposition of technical change in the basic iron and steel sector reduces the left hand side of (2.10) by 5.43%. That is, basic iron and steel producers make a cost saving of 5.43% per unit produced.

In summary, there are 3 equations in the ORANI system which are affected directly by the technical change (that is, by setting $a_{(g+1,1)63} = -22$). These are the equations modelling demands by basic iron and steel producers for labour in general and capital inputs to current production, and also the pricing equation, or zero pure profits condition, for the sector. The appearance of

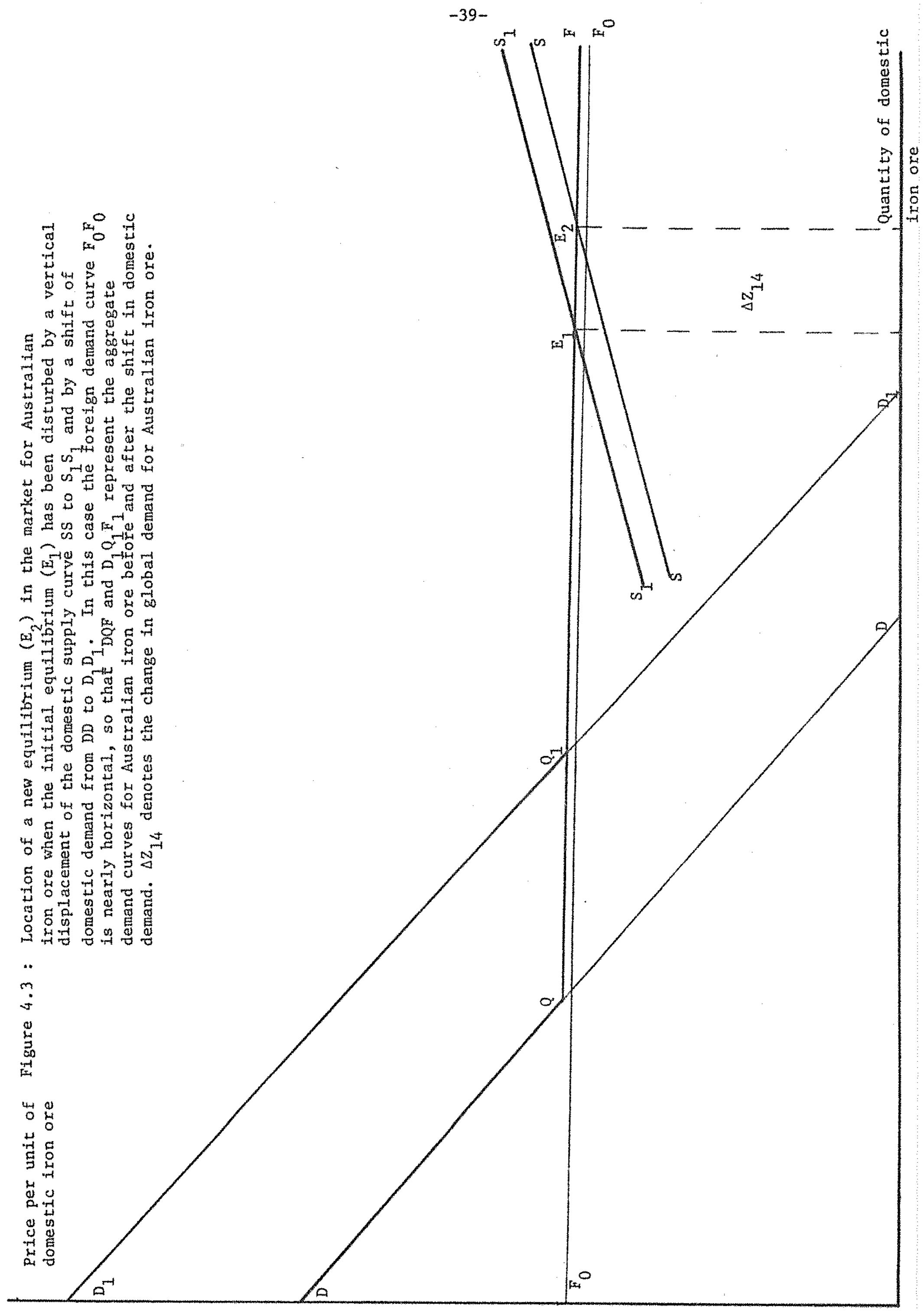


Figure 4.3 : Location of a new equilibrium (E_2) in the market for Australian iron ore when the initial equilibrium (E_1) has been disturbed by a vertical displacement of the domestic supply curve SS to S_1S_1 and by a shift of domestic demand from DD to D_1D_1. In this case the foreign demand curve F_0F_0 is nearly horizontal, so that DQF and $D_1Q_1F_1$ represent the aggregate demand curves for Australian iron ore before and after the shift in domestic demand. ΔZ_{14} denotes the change in global demand for Australian iron ore.

by D_1Q_1F. Translation from supply curve SS to schedule S_1S_1 will again produce a large reduction ΔZ_{14} in activity amongst iron miners.

The industries appearing in Table 4.2, other than the ten export activities, are classified as either export-related (ER) or import-competing (IC). Industries in the latter group sell in markets where the level of import penetration is significant and where imports and domestic output are close substitutes. If import-competing industries try to pass on cost increases their customers will substitute imported commodities for the domestic good. The export-related category consists of industries producing commodities which are not exported directly, but which are sold largely to export industries. For example industry 4, Northern beef, sells almost exclusively to the exporter, Meat products (ORANI industry 18). Because the fate of each export-related activity is closely linked to that of the export industries it supplies, the export-related industries are projected by ORANI to suffer significant output reductions.

With two exceptions the list in Table 4.3 of industries experiencing the largest output gains consist of non-traded activities which do not suffer from the cost-price squeeze imposed on other sectors. The selling prices for non-traded commodities can adjust to accomodate changes in the costs of the purchased inputs necessary for their production. Each of the industries in Table 4.3 are able to expand output by more than the increase in the level of aggregate real consumption, and each of them (except for ownership of dwellings) sell to the basic iron and steel sector.

$a_{(g+1,1)63}$ in the first of these equations implies a reduction in demand for labour in general by industry 63 at any given activity level, while in the second the term involving $a_{(g+1,1)63}$ implies decreased demand for fixed capital in production, also at fixed activity levels, due to substitution in favour of labour. Finally, the appearance of $a_{(g+1,1)63}$ in the pricing equation for industry 63 models the cost reduction per unit of basic iron and steel due to the increased efficiency of the labour input to production. The ORANI simulations trace out the general equilibrium consequences of these direct effects.

3. ORANI IN LONG-RUN MODE

3.1 Algebraic representation of the ORANI model and the neo-classical short-run environment.

ORANI is a computable general equilibrium model in the Johansen class, and so it can be written as a system of linear equations involving percentage changes in its variables. In matrix notation ORANI may be represented by:

$$Az = 0, \tag{3.1}$$

where A is an m x n rectangular matrix, and z is an n x 1 column vector. The number of variables n exceeds the number of equations m, and the model is closed by declaring n-m variables to be exogenous. If z_2 is the (n-m) x 1 vector of exogenous variables and z_1 is the m x 1 vector of endogenous variables then (3.1) may be re-written as:

$$A_1 z_1 + A_2 z_2 = 0, \tag{3.2}$$

where A_1 and A_2 are sub-matrices formed from the columns of A corresponding respectively to the endogenous and exogenous variables. Given values for z_2 the solution of ORANI is:

$$z_1 = -A_1^{-1} A_2 z_2 . \tag{3.3}$$

With the exception of the variable modelling balance of trade fluctuations[16], all of the components of z_1 and z_2 are percentage changes in ORANI variables, and therefore, so long as neither i nor j correspond to the balance of trade, the $(i,j)^{th}$ element of $-A_1^{-1}A_2$ may be interpreted as the

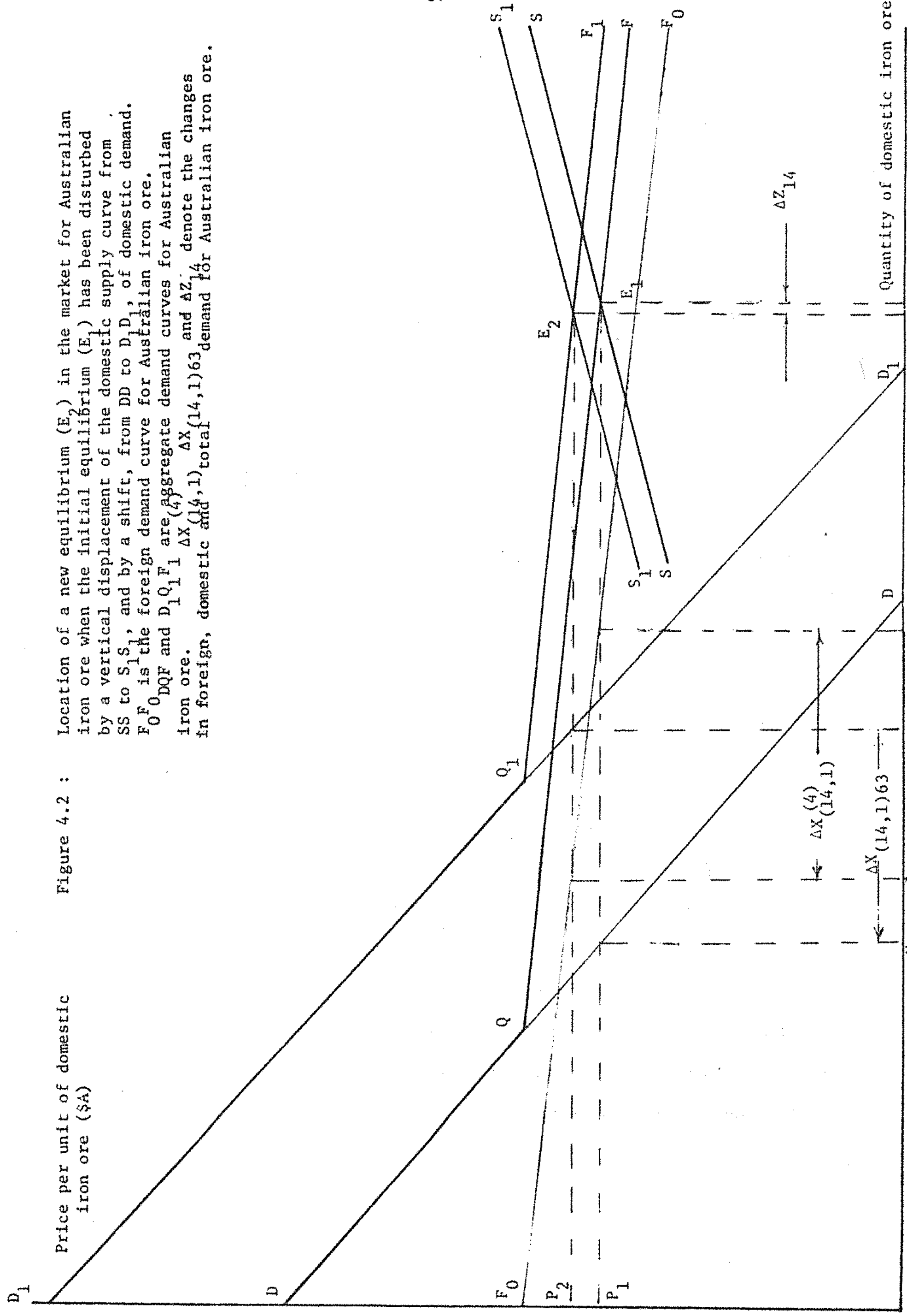


Figure 4.2 : Location of a new equilibrium (E_2) in the market for Australian iron ore when the initial equilibrium (E_1) has been disturbed by a vertical displacement of the domestic supply curve from SS to S_1S_1, and by a shift, from DD to D_1D_1, of domestic demand. F_0F_0 is the foreign demand curve for Australian iron ore. F_0DQF and $D_1Q_1F_1$ are aggregate demand curves for Australian iron ore. $\Delta X^{(4)}_{(14,1)}$, $\Delta X_{(14,1)63}$ and ΔZ_{14} denote the changes in foreign, domestic and total demand for Australian iron ore.

Basic iron and steel producers account for almost all of the domestic iron ore used in Australia, so that the 30.40% expansion of activity in the sector (see Table 4.3) following the labour-augmenting technical change represents a marked shift in domestic demand for iron ore. In Figure 4.2 this shift in demand is represented by the transition from schedule DD to schedule D_1D_1. Figure 4.2 also reproduces the curves of Figure 4.1, and further shows schedule $D_1Q_1F_1$, which is the horizontal aggregation of the new demand schedule D_1D_1 with the foreign demand curve F_0F_0. E_1 denotes the initial equilibrium in the global market for Australian iron ore. After the increase in labour productivity equilibrium in the market for Australian iron ore is re-established at E_2. At the initial equilibrium price (P_1) the quantities of domestic iron ore consumed in domestic and foreign markets are respectively H_1 and I_1; while at the price (P_2) corresponding to the new equilibrium E_2 the quantities of Australian iron ore consumed in domestic and foreign markets are H_2 and I_2. Notice now that there is an <u>expansion</u> of domestic demand from H_1 to H_2 (which is denoted by $\Delta X_{(14,1)63}$) while, as was the case in the situation of Figure 4.1, there is a large <u>contraction</u> in foreign demand for Australian iron ore from I_1 to I_2 (which is denoted as $\Delta X^{(4)}_{(14,1)}$). The net effect is that aggregate demand for Australian iron ore contracts only slightly. This contraction is shown as ΔZ_{14} in Figure 4.2. The essential feature of the ORANI theory in the operation of the market for iron ore is that foreign demand for this commodity is <u>not</u> perfectly elastic. That is, in Figure 4.2 the schedule F_0F_0 is not horizontal. To see the impact of this feature of the theory, suppose that F_0F_0 is approximately horizontal. In Figure 4.3, where the initial aggregate demand curve is given by DQF, then, following the shift in domestic demand, the aggregate demand schedule may be approximated

elasticity of endogenous variable i with respect to exogenous variable j. For example, the $(i,j)^{th}$ entry of $-A_1^{-1}A_2$ might be the percentage change in the employment of labour of skill class m resulting from a 1% across the board labour-augmenting technical change in the basic iron and steel industry.

An important feature of ORANI which enhances its flexibility in policy applications is that the division of ORANI variables into exogenous and endogenous categories is user determined. One user might wish to study the effects of labour-augmenting technical change on industry outputs, in which case the technical change terms $a_{(g+1,1)j}$ would be allocated to the exogenous list (that is, included in z_2 in (3.2)), while industry output levels would be assigned to z_1. Alternatively, to answer the question:

> What level of labour-augmenting technical change in the basic iron and steel sector would raise output in that industry by 10%?

then the variable $a_{(g+1,1)63}$ would be included in z_1 and industry 63's activity level must be assigned to z_2.

For most ORANI applications reported to date[17] the list of exogenous variables has been chosen to produce a neo-classical short-run environment, in which the capital stock available to each industry in the solution period is held fixed, and shocks imposed on the model are allowed to alter each industry's rate of return. With industry capital stocks fixed, ORANI simulates the effects of exogenous shocks after a period which is shorter than that required for any industry to bring into use capital stock acquired during this period. The appropriate calendar time interpretation of this solution period is about 2 years.[18]

The following macroeconomic assumptions are usually made in short-run simulations:

(i) the real values of domestic expenditure aggregates (that is, aggregate real investment, consumption and government spending) are exogenous; and

(ii) occupational labour markets are slack with exogenous real wage rates.

By placing the real components of domestic expenditure on the exogenous list the assumption is that these aggregates are controlled independently of the other exogenous variables by policy makers using macro instruments, an explanation of which is not included in ORANI. Alternatively users could replace the components of domestic absorption on the exogenous list by the balance of trade. Then ORANI would project the change in the level of domestic absorption needed to maintain a given level for the balance of trade when, say, tariffs are reformed. The current version of ORANI does not explain the allocation of this changed level of domestic absorption between investment and consumption, but rather this must be imposed exogenously.

The reason for setting real wage rates exogenously is that institutional factors are seen as preventing their adjustment in the short-run. Thus, producers can employ as much labour as they require in all occupations at fixed real wages. This implies that the level of employment is demand determined, which is appropriate in conditions of general unemployment.

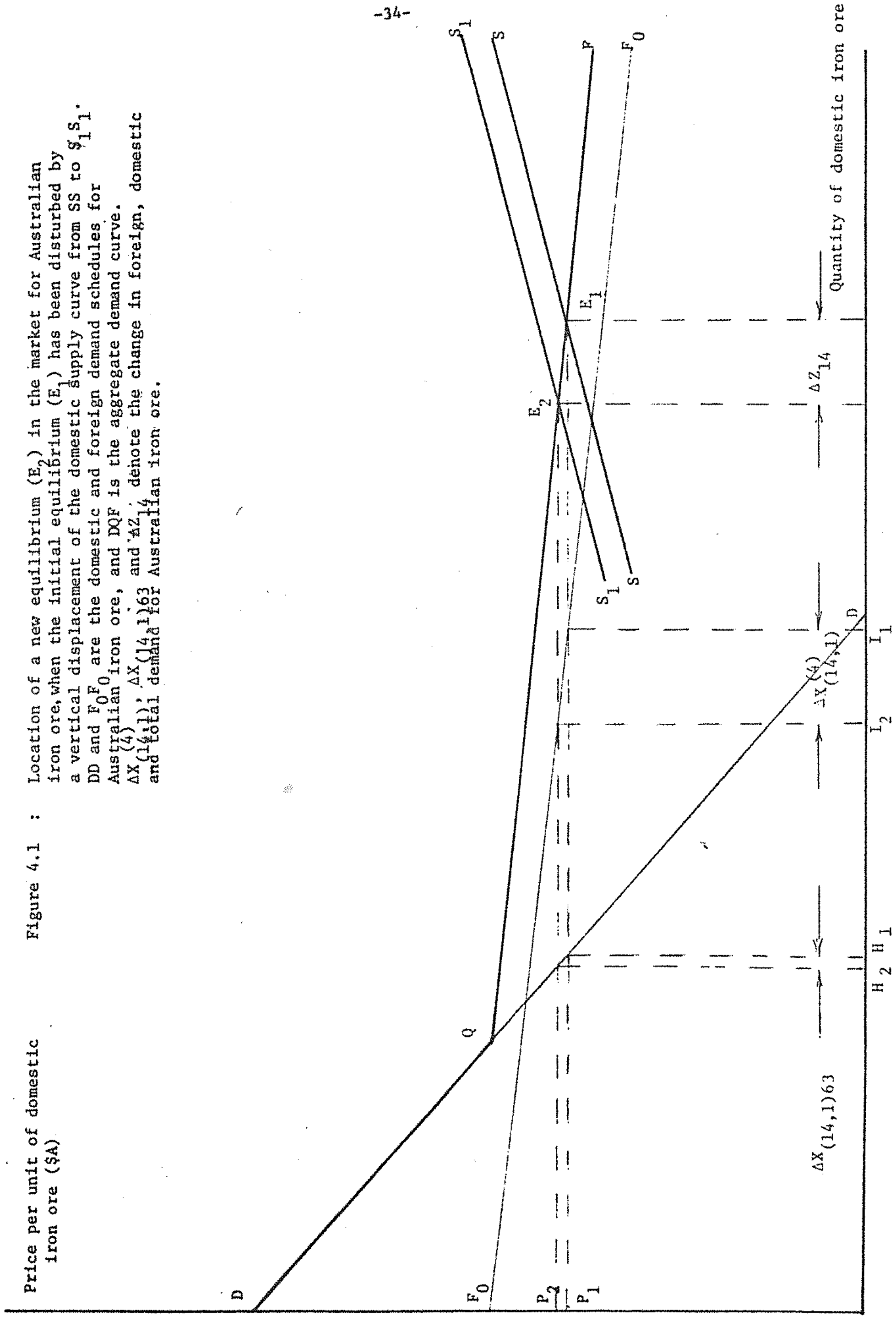
3.2 The snapshot approach to long-run simulations with ORANI.

For the simulation reported in section 4, ORANI has been solved with industries' capital stocks for the solution year endogenous and

curve. This is represented in each figure by the transition from supply schedule SS to supply schedule S_1S_1.[29] If this had been the only change then the ORANI results would show a large loss of activity in the extraction of iron ore. This is demonstrated in Figure 4.1 where F_0F_0 represents the foreign demand curve, DD represents the domestic demand schedule, and the schedule DQF is the (horizontal) aggregation of the foreign and domestic demand curves.

Prior to the increase in costs, the domestic iron ore industry operates on supply curve SS, with equilibrium in the global market for Australian iron ore occurring at the price and quantity combination E_1. At the initial equilibrium price (denoted P_1) the domestic market absorbs quantity H_1, and the level of foreign demand for Australian iron ore is given by I_1. After the increase in costs the industry shifts to supply schedule S_1S_1 which intersects the aggregate demand curve at the price and quantity point E_2. At this new price (denoted by P_2) the level of domestic demand contracts to H_2, while the level of foreign demand is reduced to I_2. To maintain consistency with the (percentage) change notation used in (4.4), the reduction from I_1 to I_2 is denoted by $\Delta X^{(4)}_{(14,1)}$ (i.e., the actual change in exports of iron ore), the contraction from H_2 to H_1 in domestic demand is denoted by $\Delta X_{(14,1)63}$, and the overall change in activity in the domestic iron ore industry is given in Figure 4.1 as ΔZ_{14}. Because the foreign demand curve is quite elastic the reduction $\Delta X^{(4)}_{(14,1)}$ in the quantity sold on international markets is large (while there is also a small contraction $\Delta X_{(14,1)63}$ in the quantity sold on the domestic market). Thus the supply curve shift causes a large contraction ΔZ_{14} in activity by iron ore miners. This explanation is not consistent with the ORANI projection of only a slight (0.33%) contraction in iron ore mining. The feature missing from Figure 4.1 is the influence of a shift in domestic demand.

Figure 4.1 : Location of a new equilibrium (E_2) in the market for Australian iron ore, when the initial equilibrium (E_1) has been disturbed by a vertical displacement of the domestic supply curve from SS to S_1S_1. DD and F_0F_0 are the domestic and foreign demand schedules for Australian iron ore, and DQF is the aggregate demand curve. $\Delta X^{(4)}_{(14,1)}$, $\Delta X_{(14,1)63}$ and ΔZ_{14} denote the change in foreign, domestic and total demand for Australian iron ore.



rates of return exogenous, which is the reverse of the assignment of these variables described in sub-section 3.1 for the model's short-run mode. In this new configuration the ORANI solution period is assumed to be a calendar time sufficiently long to allow the impact of the shock (a 22% labour-augmenting technical change in the basic iron and steel industry) on each industry's rate of return to be eliminated by the expansion or contraction of capital stocks. The justification for this assumed time period is that in the long-run rates of return are set by factors (for example, fluctuations in world capital markets), other than the technical change imposed, and further, in the long run, the impact of the shock will be on the levels of industries' capital stocks rather than on rates of return. A 10 year calendar time period is probably an appropriate approximation to the implied ORANI solution period. With this interpretation of the ORANI solution period, a solution z_1 obtained from (3.3) provides a "snapshot" of the economy in a typical year 10 years after the imposition of the technical change. Consequently, the solution period for the model in this configuration (i.e., 10 years) is called the "snapshot period", and the typical year (following the snapshot period) for which ORANI provides a view of the economy is referred to as the "snapshot year".

Two things should be noted. First, the vector z_1 obtained from (3.3) contains the percentage departure of each endogenous variable from the value it would have attained in the snapshot year if the 22% labour-augmenting technical change had not occurred; and second this snapshot methodology does not trace out the time paths of endogenous variables through the snapshot period. These points can be demonstrated using Figure 3.1 which has been borrowed from Parmenter.[19] In this diagram time is plotted on the horizontal axis, and the levels attained by an endogenous ORANI variable X_j are recorded on the vertical axis. The solid curve in the figure shows the path which the variable X_j might be assumed to follow in the absence of the shock imposed at $t = 0$. (For this work $t = 0$ corresponds to a view of the Australian economy obtained from the 1974-75 ABS input-output tables.) The value a represents the level X_j would attain in the snapshot year (that is, at t^*). When a shock is imposed at $t = 0$ (like a labour-augmenting technical change) the path of X_j is represented by the broken line in Figure 3.1. From the point of view of the snapshot approach the only important point on this curve is (t^*,b), where b is the value of X_j in the snapshot year when the shock has been applied in the base year, $t = 0$. The percentage change in X_j from its ceteris paribus value a at t^* is given by:

$$x_j = \frac{b-a}{a} \times 100.$$

It is this percentage change which is obtained as part of the solution z_1 of the ORANI model given by (3.3).

An alternative[20] to the snapshot methodology would be to generate a long-run solution over 10 years by accumulating changes in the endogenous variables, including next period capital stocks, over a number of 1 to 2 year short-run solutions. This would allow the time paths of endogenous variables to be traced from period to period. In each of these short-run solutions the availability of capital to each industry in the next period depends on the exogenously

simulation reported here), agricultural exporters tend to show considerably less output volatility than do other exporting activities.[28] One mining based export industry undergoes only a small loss in activity and so does not appear in Table 4.2. This is the iron industry, which in the base year supplied 75.6% of its output to international markets and 21.2% to the basic iron and steel sector. The expanded demand for iron by the booming basic iron and steel sector nearly matches the loss of sales of iron on international markets. An approximation to the net effect on the iron industry can be obtained as follows. Estimate z_{14}, the percentage change in output of iron mining (ORANI industry 14) by:

$$z_{14} = B^{(4)}_{(14,1)} \, x^{(4)}_{(14,1)} + B_{(14,1)63} \, z_{63}, \qquad (4.4)$$

where $B^{(4)}_{(14,1)}$ and $B_{(14,1)63}$ are the shares (given above in percentage form) of total sales of domestically produced iron to exports and to the basic iron and steel industry as an input to current production, and $x^{(4)}_{(14,1)}$ is the percentage change in exports of iron ore. The simulation gives $x^{(4)}_{(14,1)} = -8.96$ and $z_{63} = 30.40$, hence:

$$z_{14} = 0.756 \times (-8.96) + 0.212 \times 30.40$$

$$= -6.77 + 6.45$$

$$= -0.32\% .$$

This agrees closely with the output contraction of 0.33% projected for the iron industry by ORANI.

The operation of the market for Australian iron ore can be explained using Figures 4.1 and 4.2. Due to an increase in costs in the extraction of iron ore there is an upward shift in the industry's supply

Table 4.3: **ORANI projections of the outputs of industries which experience the greatest expansion of output as a result** of a 22 per cent labour-augmenting technical change in the basic iron and steel industry

Rank	ORANI industry number	Description	Projection (percent)	Trade Category
104	103	Ownership of dwellings	0.59	NT
105	69	Ship and boat building	0.69	NT
106	51	Paints, varnishes	0.77	NT
107	36	Textile products (nec)	0.78	IC
108	50	Industrial chemicals	0.95	NT
109	84	Electricity	1.11	NT
110	62	Non-metal mineral products	1.21	NT
111	16	Non-metallic minerals (nec)	1.27	NT
112	58	Clay products	2.32	NT
113	63	Basic iron and steel	30.40	E

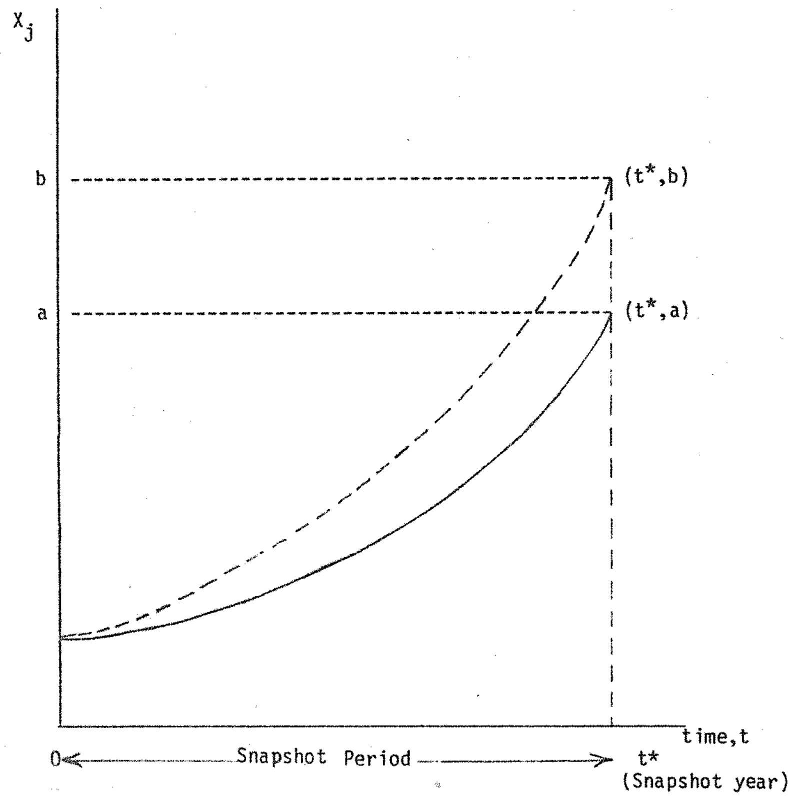


Figure 3.1: Time paths of development of endogenous ORANI variable X_j when an exogenous technical change occurs (broken line), and when no such change occurs (solid line)

determined industrial capital endowments at the commencement of the 10 year period, and net investment generated endogenously by the previous short-run solutions. This accumulation approach relies heavily on ORANI's short-run investment mechanism for the long-run determination of the relative sizes of industries' capital stocks.

3.3 The long-run scenario

For the ORANI simulation reported in section 4 partial lists of exogenous and endogenous variables are given in Table 3.1. The choices of other exogenous variables for this work are the same as those made by DPSV and shown in their Table 23.3.[21] In this sub-section the assignment of those variables shown in Table 3.1 to the exogenous category is discussed.

As has already been noted the inclusion of industry rates of return on the exogenous list embodies the idea that, in the long run, these rates are unaffected by the 22% labour-augmenting technical change. Adjustment to the shock occurs via industry capital stocks, with industries favoured by the change growing relative to other sectors. Similarly, the economy is seen as operating as a small country in an open world market, so that in the long term, the average rate of return in the domestic economy is exogenous, and the percentage change k in the aggregate ORANI capital stock is allowed to adjust. This accounts for the inclusion of the variables $r_j(0)$ on the exogenous list in Table 3.1.

The second variable on the exogenous list is aggregate employment ℓ. With the focus on long-run developments in this paper it is appropriate to assume that changes in aggregate employment are independent of the labour-augmenting

Table 4.2: ORANI projections of the outputs of industries which suffer the heaviest output losses as a result of a 22% labour-augmenting technical change in the basic iron and steel industry

Rank	ORANI industry	Description	Projection (percent)	Trade Category
1	14	Coal	-9.46	E
2	17	Services to mining	-6.14	ER
3	25	Food products (nec)	-5.08	E
4	4	Northern beef	-4.80	ER
5	13	Other metallic minerals	-4.73	E
6	6	Other farming export	-3.70	ER
7	64	Other basic metals	-3.68	E
8	22	Flour and cereal products	-3.63	E
9	18	Meat products	-2.71	E
10	3	High rainfall zone	-2.65	E
11	1	Pastoral zone	-2.09	E
12	30	Prepared fibres	-1.91	E
13	2	Wheat-Sheep zone	-1.84	E
14	49	Chemical fertilizers	-1.84	ER & IC
15	9	Services to agriculture	-1.65	ER
16	76	Agricultural machinery	-1.34	IC & ER
17	31	Man-made fibres	-1.25	IC
18	8	Poultry	-1.16	ER
19	32	Cotton, silk, flax	-1.01	IC
20	94	Railway transport	-0.98	ER

total wage bill for this category in the base year) and to the expansion of activity in the basic iron and steel industry (which accounted for 4.53% of the occupational group's base year wage bill).

The nine-order occupation classification is insufficiently industry-specific to give a clear reflection of the employment effects in the basic iron and steel industry, and the import competing and non-traded sectors.[26]

4.2 Industry results

Tables 4.2 and 4.3 contain projections of the percentage effect of the labour-augmenting technical change on industrial output for some of ORANI's 113 industries. The results are ranked consistently over the two tables, in that the industry which experiences the heaviest loss, in terms of its output level, appears first in Table 4.2, while the industry with the largest output gain appears last in Table 4.3. The final column in each of these tables assigns to each industry an international trade classification. Following DPSV four classifications are used: industries are classified as import-competing (IC), exporting (E), export-related (ER) or non-trading (NT).[27]

Ten industries designated as exporters appear in the first thirteen rows of Table 4.2. These ten industries produce 11 of the 13 commodities whose export levels are determined endogenously by ORANI. In Table 4.3 the exporter, basic iron and steel, which experienced the labour-augmenting technical change, is recorded as the industry which makes the greatest gain in output. As pointed out in the previous sub-section exporters (other than the basic iron and steel sector) face a domestic cost-world price squeeze. This explains the large output contractions in exporting activities other than basic iron and steel production. Because agricultural exporters use the fixed factor land (while other exporters are assumed to have no fixed factors in the

technical change. The assumption is that technical change is not an important determinant of the aggregate level of employment 10 years hence, but rather it depends specifically on demographic factors, fiscal and monetary policy, and the relationship between labour productivity and the real wage rate. In this simulation it is assumed that the level of employment in the snapshot year is fixed. That is, ℓ is set at zero. This level of employment is achieved by the endogenous adjustment of the overall level of real wages in response to the labour-augmenting technical change. In the ORANI simulations $f_{(g+1,1)}$ measures the average real wage, and consequently this variable appears on the endogenous list in Table 3.1. (In their work on technical change Hagan and Smith (1980, p.18) assumed that labour is available in unlimited supply at a given money wage rate.)

The third group of variables on the exogenous list comprises $f_{(g+1,1,m)}$, for m = 1,2,...,M. These are the percentage changes in real occupational wage relativities, which are fixed so as to reflect the operation of institutional rigidities in the labour market. In the simulation occupational employment levels ℓ_m are allowed to adjust to the technical change in accordance with the fixed wage relativities.

Table 3.1: Partial lists of exogenous and endogenous variables for the long-run simulation[(a)]

Exogenous Variable	Endogenous Variable	Number of Components
$r_j(0)$	$k_j(0)$	h
ℓ	$f_{(g+1,1)}$	1
$f_{(g+1,1,m)}$	ℓ_m	M
ΔB	c_R	1
f_R	i_R	1

Footnote:
(a). The selection of other exogenous variables are the same as those made by DPSV and which are given in their Table 23.3.[21]

The remaining exogenous variables are the change in the balance of trade ΔB, and f_R, the percentage change in the ratio of real consumption (C_R) to real investment (I_R). In this configuration ORANI will simulate the change in real domestic absorption in the snapshot year which must accompany a technical change, say, given a constant balance of trade. The current version of ORANI does not explain the distribution of the change in domestic absorption amongst its components (aggregate consumption, aggregate investment, and aggregate government spending). Hence f_R appears on the exogenous list, and the changes in domestic absorption will be allocated according to the initial shares of its components. (Hagan and Smith (1980) assume that real domestic absorption is fixed.)

In long-run simulations it would be better to treat c_R and i_R as well as ΔB and f_R as endogenous for the following reason: ORANI may report that $k = 10$ as the result of a labour-augmenting technical change. That is, there is a 10% growth in aggregate capital stocks at the beginning of the snapshot year, over that which would have occurred if the technical change had not arisen. The effect of the technical change on the components of domestic absorption and the balance of trade will depend on the manner in which the expansion of the capital stock was financed over the snapshot period. If the extra capital was purchased by foreign investors, then the income accruing from it in the snapshot year would be reflected in an increased balance of trade surplus corresponding to additional profit repatriation. However, if the extra capital was owned domestically, then in the snapshot year this would emerge as real increases in domestic spending. In the current version of ORANI there is no explicit theory of the ownership of capital, although the inclusion of such a theory into a miniature version of ORANI has been recently completed.[22] Implementation of a similar theory for ORANI is currently underway.

percentage as aggregate consumption, and an increasing nominal wage level, which is due to the competition for labour in an environment of fixed labour supply. This is detrimental to exporters (although in the case of basic iron and steel producers not sufficiently detrimental to offset completely the direct effects of the technical change) who face increasing production costs, while the selling prices of their international competitors are largely independent of domestic developments. Moreover import-competing industries are unable to pass on cost increases as their customers will substitute (albeit, imperfectly) imported goods (from the same commodity classification) if the price of the domestic product rises. An additional cause of the rise in imports is the direct increase in demand for imports flowing from the increase in domestic absorption. There is a redistribution of resources between the traded and non-traded sectors, which leads to changes in the occupational composition of the workforce.

Table 4.1 reveals that seven of the nine ORANI occupations experience small gains with two occupational groups suffering declines in employment. Rural workers are primarily employed in agricultural activities, and demand for this group declines in line with the cost-price squeeze experienced by agricultural export industries. In the 1974-75 input-output database 18.8% of employment in the skilled blue collar (other) category is concentrated in the export-oriented meat products industry. It is contraction of the output of this sector which accounts for nearly all of the fall in employment in the occupation.[25]

The fourth occupation, skilled blue collar (metal and electrical), experiences the largest net increase in employment. This is predominantly due to the growth in the non-traded sector (which accounted for 48.3% of the so that aggregate real investment grows by the same percentage as aggregate real consumption. Further the level of aggregate government spending is fully indexed to the level of real consumption, and so,

$$a = c_R.$$

For the simulation ΔB was exogenous with $\Delta B = 0$, and therefore (4.1) estimates gdp as

$$\begin{aligned} gdp &= S_A\, a \\ &= S_A\, c_R \\ &= 0.97 \times 0.32 \quad \text{(see Table 4.1)} \\ &= 0.31 \end{aligned}$$

Thus, the consistency check is very close.

In the 1974-75 input-output data used for this work, exports constitute approximately 20% of the output of the basic iron and steel sector. For 12 other commodities exports amount to 20% or more of their total base-year sales, and are a sufficiently important component of total sales to require that the domestic prices and export quantities of each of these 13 commodities be modelled as responding to changes in the domestic currency value of world prices. In ORANI these "export commodities" (with the exception of wool) face relatively flat overseas export demand curves. Quantities exported of the remaining ORANI commodities are held exogenously constant. The labour-augmenting technical change improves the competitive position of Australian basic iron and steel producers relative to international competitors. Hence the balance of trade tends to move towards surplus, and external balance is achieved via an increase in the domestic price level relative to world prices.[24] The required increase in domestic prices is generated by the growth of domestic absorption, which increases by the same

4. RESULTS OF THE ORANI SIMULATION OF A 22 PER CENT LABOUR-AUGMENTING TECHNICAL CHANGE IN THE BASIC IRON AND STEEL INDUSTRY

4.1 Macroeconomic and employment indicators

Table 4.1 contains projections for selected macroeconomic and employment variables. The figures presented in each of the tables in this section refer to percentage changes in the variables from the levels they would have reached in the snapshot year in the absence of the technical change. Thus the figure in row 1 of Table 4.1 indicates that the occurrence of the technical change would raise the real wage in the snapshot year to a level 0.66% higher than would have been the case had the technical change not occurred.

Increased labour productivity in the manufacture of basic iron and steel reduces the costs of production of this commodity, and also the unit costs of commodities that are produced using basic iron and steel as an intermediate input. The marginal product of labour is increased by the labour productivity gain so that it exceeds the snapshot year real wage, making it profitable to hire more labour. The increased demand for labour raises the economy's snapshot year real wage as, in this work, it was assumed that labour is fully employed in the snapshot year. The result is that the economy is able to obtain a 0.66% higher level for the absolute real wage with no effect on the snapshot year level of employment. Aggregate consumption grows by 0.32%, and given the assumption of exogenous rates of return set in international capital markets, the economy's aggregate capital stock will be larger by 0.37%. The reductions in production costs (flowing from the increased productivity of labour in basic iron and steel production) would

Table 4.1: Projections of the long-run effects on macroeconomic and employment variables of a 22 per cent labour-augmenting technical change in the basic iron and steel industry

Variable	Projection (per cent)
Absolute real wage	0.66
Aggregate real consumption	0.32
Aggregate capital stock	0.37
Consumer price index	1.01
Aggregate imports	1.17
Aggregate exports	1.16
Employment by occupation :	
Professional white collar	0.15
Skilled white collar	0.15
Semi- and un-skilled white collar	0.15
Skilled blue collar (metal and electrical)	0.36
Skilled blue collar (building)	0.24
Skilled blue collar (other)	-0.56
Semi- and un-skilled blue collar	0.05
Rural workers	-2.16
Armed services	0.31

otherwise stimulate exports and also provide import-competing industries with a competitive advantage over imports, thus generating a balance of trade surplus. (For example, see the results in Tables 2 and 4 of the work on input-augmenting technical change by Hagan and Smith (1980).)

A check on the aggregate capital and aggregate absorption results is available via the national income identity. The percentage change in gross domestic product (GDP), denoted gdp, is given by :

$$gdp = S_A a + \Delta B/GDP , \qquad (4.1)$$

where a is the percentage change in real domestic absorption, S_A is the share of domestic absorption in GDP, and ΔB is the change in the balance of trade. The percentage change in GDP can also be measured as a weighted average of percentage changes in the employment of primary factors and technical changes which occur, that is,

$$gdp = S_K k + S_N n + S_L \ell - S_{63} a_{(g+1,1)63} , \qquad (4.2)$$

where k, n and ℓ are percentage changes in the employment of capital, land and labour; $a_{(g+1,1)63}$ denotes the variable modelling labour-augmenting technical change in the basic iron and steel sector (ORANI industry 63); and S_K, S_N, S_L and S_{63} are the shares of returns to capital, land, all labour, and labour employed by industry 63 in GDP.[23] For the long-run simulation

$$\ell = n = 0,$$
$$k = 0.37 \text{ (see Table 4.1) and } a_{(g+1,1)63} = -22.0 . \qquad (4.3)$$

The values of S_K and S_{63} in the data base are 0.22 and 0.01, so that (4.2) and (4.3) realise a value for gdp of about 0.31. The distribution of domestic absorption between consumption and investment is exogenous,