IMPACT PROJECT

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

THE SNAPSHOT MODEL : UNDERLYING THEORY AND AN APPLICATION TO THE STUDY OF THE IMPLICATIONS OF TECHNICAL CHANGE IN AUSTRALIA TO 1990

by

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Preliminary Working Paper No. SP-14 Melbourne October 1979

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

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1. INTRODUCTION

During the last four years two separate input-output based models of the Australian economy have been built as part of the IMPACT Project.[1] The first model, ORANI, was intended for answering short to medium term questions while the second, SNAPSHOT, was intended for making projections 10 or more years into the future. This paper is about SNAPSHOT. Nevertheless, it will be useful in this introductory section to make some brief comments on ORANI by way of comparison.

ORANI can be placed in the Johansen class of models.[2] Johansen type models are built up from standard microeconomic assumptions of cost minimization, profit maximization and utility maximization applied at the industry and household-sector level.

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* The authors are indebted to Alexandra Strzelecki for programming the current version of the SNAPSHOT model and to Alan Powell and Tony Lawson for helpful comments.

1. For a complete but non-technical description of the IMPACT Project, see Powell [1977].

2. So named in recognition of the contribution of Johansen [1960]. See also Taylor and Black [1974], Klijn [1974] and Staelin [1976].

They employ neoclassical production and utility functions and emphasize the role of prices and substitution possibilities in determining the composition of economic activity. SNAPSHOT, on the other hand, is a programming model of the type commonly found in the development literature.[1] These models are often specified as linear (or perhaps non-linear) programming problems. That is, the economy is viewed as if it maximizes an objective function (e.g., utility associated with household consumption) subject to a set of production possibilities, a balance of payments constraint and perhaps additional constraints ensuring adequate diversification of investment and employment across sectors, satisfactory income distribution, etc.. In this paper, however, we have preferred to present SNAPSHOT as a series of equilibrium conditions rather than as a programming problem. The programming formulation is, we think, best regarded as part of the computational technique for solving the set of equilibrium conditions (see section 2(f) below) rather than as a means of explaining the model's theoretical structure.[2]

Traditionally, Johansen models have been restricted to short-run solutions. Such solutions are characterized by the assumption of fixed capital stocks in each industry.[3] Where longer-run results have been required, a series of linked short-run solutions have been

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1. Well known examples of programming models are Sandee [1960], Manne [1963], Bruno [1966] and Evans [1972]. It was Evans' work on the Australian economy which provided the principal inspiration for our current efforts.

2. The argument against the programming formulation is developed in Dixon and Butlin [1975, 1977].

3. See for example, Taylor and Black [1974].

made.[1] By contrast, in the programming models it has generally been assumed that capital is freely mobile between industries. This assumption is sensible only for long-run projections where sufficient time is allowed for the capital stock to adjust completely (via depreciation and investment) to whatever exogenous shock is under investigation.

Given the long-run nature of the programming class of models, it was natural for us to associate SNAPSHOT with the analysis of technical change and demographic issues. In fact, the illustrative application of SNAPSHOT given in section 4 is concerned with the implications of technical change to 1990/91 for the industrial structure of Australia's GDP, the occupational composition of the workforce and the material standard of living. Our results underline the importance of using a multisectoral framework. Technical change in any one industry has specific effects on the performances of other industries via input-output linkages and general effects via the balance of payments.

Contrary to our initial expectations, we have found that ORANI (originally conceived as a short to medium term model) can also be applied to longer term issues by relaxing the assumption of fixed industry-specific capital stocks.[2] Although ORANI in long-run mode currently does not have the operational capacity for handling technical change (an area originally designated as a SNAPSHOT speciality) the

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1. This is the approach of, for example, Adelman and Robinson [1978].

2. For long-run applications of ORANI, see for example, Dixon, Harrower and Powell [1977] and Vincent, Dixon, Parmenter and Sams [1979]. This latter paper uses the most recent version of ORANI, ORANI 78. For notes on alternative theoretical approaches to long-run modelling within the ORANI framework, see Dixon, Parmenter and Sutton [1978].

relevant theory has been worked out.[1] Thus providing limitations imposed on ORANI by the adoption of Johansen's linearization technique can be overcome,[2] we would envisage ORANI eventually superseding SNAPSHOT as a long-run model. This would be a significant step forward. As will become apparent, SNAPSHOT (in common with most programming models) has serious limitations in its handling of price responses and substitution possibilities especially as they relate to international trade. In this area ORANI (in common with most Johansen-type models) has a distinct advantage.

We present this paper with two aims. The first is to describe the application of SNAPSHOT to the analysis of some of the long-run implications of technical change. The second is to document some of the difficulties we see with the SNAPSHOT theory and, more generally, with the theory underlying many models of the programming type. The paper is organized as follows. In section 2 we work through a stripped-down version of SNAPSHOT. We try to explain the essentials of the theory without introducing an immense number of practical details.[3] Then in section 3 we consider the particular problems involved in specifying international trade. The application of SNAPSHOT to the analysis of the effects of technical change is in section 4. Subsection 4.1 describes the projections for the exogenous

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1. See Dixon [1978] or Vincent [1978].

2. Johansen's linearization technique (which is adopted in our current ORANI computations) is valid only for the analysis of the effects of small changes in the exogenous variables. This may be particularly limiting for long-run applications. We are currently undertaking research aimed at eliminating linearization approximations from our ORANI computations. See Dixon [1979, section 5].

3. SNAPSHOT is fully documented in Dixon, Harrower and Powell [1976], Dixon [1976] and Dixon, Harrower and Vincent [1978].

variables. These come from many sources including a survey by the Bureau of Industry Economics of the views of industry experts regarding future techniques of production. Subsection 4.2 contains the SNAPSHOT projections and uses them in a discussion of the effects of foregoing technical progress. Brief concluding remarks are in section 5.

2. A STRIPPED-DOWN VERSION OF SNAPSHOT

Table 2.1 sets out a stripped-down version (SDV) of the SNAPSHOT model. We simplify SNAPSHOT by leaving out government spending, production taxes, capital depreciation, inventories and margins. We recognize only one type of labour and treat the household sector as a single consumer. Most importantly, in the stripped-down version we omit international trade.[1] Nevertheless, we feel that SDV is a useful model of SNAPSHOT. It will give hurried readers an adequate account of SNAPSHOT's theoretical structure and potential applications.

SDV, in common with SNAPSHOT, is a single-period model. All of the equations refer to relationships existing between variables in a particular year called the snapshot year. For example, by imposing equation (2.1) we assume that in the snapshot year the vector of commodity supplies (X) equals the vector of commodity demands. The vector of commodity demands is the sum over household demands (C), demands for inputs into capital creation (KJ) and demands for intermediate inputs (AX).

Equation (2.2) sets the level of employment (N) in the snapshot year and implies that aggregate demand for labour (ℓX) is satisfied.

Equation (2.3) says that in the snapshot year, household demands for commodities will be determined by commodity prices (P) and the level of household expenditure (Y). These equations are the

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1. The treatment of international trade is discussed separately in section 3.

Table 2.1 The SNAPSHOT Model : A Stripped-down Version

1. EQUATIONS

Identifier	Description	Equations	Number
2.1	Demands equals supplies for commodities	$X = C + KJ + AX$	n
2.2	Employment level	$\ell X = N$	1
2.3	Household demands for commodities	$C = f(P, Y)$	n
2.4	Zero pure profits in all activities	$P' = P'A + W\ell + rP'K$	n
2.5	Investment by investing industry	$J = GX$	n
2.6	Numeraire	$W = 1$	1
			4n + 2

2. ENDOGENOUS VARIABLES

Variable	Description	Number
C	Household consumption vector	n
P	Commodity prices	n
Y	Household expenditure level (P'C)	1
J	Investment by investing industry	n
X	Commodity output levels	n
W	Wage rate	1
		4n + 2

3. EXOGENOUS VARIABLES OR PARAMETERS

Variable or Parameter	Dimension	Description
G	n × n	Diagonal matrix of exogenous growth rates for the snapshot year.
K	n × n	Capital matrix. K_{ij} is the input of good i required to create a unit of capital for industry j . Units are defined so that each industry requires one unit of capital per unit output per year.
A	n × n	Input-output coefficient matrix. A_{ij} is the input of good i required per unit of output of good j .
ℓ	1 × n	Labour coefficient vector. ℓ_j is the input of labour required per unit output of good j.
N	1 × 1	Total availability of labour.
r	1 × 1	Rate of return on capital in the snapshot year.

solution to a utility maximizing problem of the form :

$$\left.\begin{array}{l} \text{choose } C \text{ to maximize} \\ \qquad U(C)\ , \\ \text{subject to } P'C = Y\ . \end{array}\right\} \qquad (2.7)$$

Equation (2.4) equates commodity prices to unit costs. Unit costs include intermediate inputs ($P'A$), labour ($W\ell$) and rentals on capital ($rP'K$). Notice that in the snapshot year, the rate of return on units of capital in each industry is r .[1] Thus the costs of using units of capital (or the rentals) are given by $rP'K$, i.e., the rate of return multiplied by the cost of building a unit of capital.[2]

Equation (2.5) describes investment in the snapshot year. The number of new units of capital created for industry j in the snapshot year is given by

$$J_j = G_j X_j \ , \qquad (2.8)$$

i.e., equation (2.5) provides for growth in industry j at the exogenous rate G_j .

The final equation (2.6) sets the absolute price level in the snapshot year by using the wage rate as the numeraire.

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1. We can think of r as being determined in international capital markets. This would justify its exogeneity. It should also be noted that in SNAPSHOT we have an exogenous vector of industry rates of return rather than a single economy-wide rate. This allows the model to produce projections which are consistent with observed long-run deviations across industries in their rates of return, associated with barriers to entry and differences in riskiness.

2. We assume, for this illustrative model, that depreciation rates are zero.

From Table 2.1 we see that SDV has $4n+2$ equations[1] and $4n+2$ endogenous variables. If we were given information for the snapshot year on

(i) technology (i.e., A, K and ℓ),

(ii) demographic factors, so that household preferences (the function U) can be specified thus allowing the derivation of f,

(iii) the size of the workforce (N),

(iv) the industry growth rates (G),

and

(v) the economy-wide rate of return (r),

then we would expect to be able to compute for the snapshot year : industry outputs and investment levels (X and J), the vector of commodity prices in terms of wage units (P/W), household demands (C) and the household expenditure level (Y). This suggests that the principal applications of SNAPSHOT concern the implications for the size and industrial composition of GDP of changes in technology (i.e., changes in the A, K and ℓ matrices) and demographic changes which affect N, U and hence f. Section 4 does in fact report results on the effects of changes in technology. However, before we turn to those results, it might be helpful if we try to clarify some particular aspects of the SNAPSHOT theory especially with regard to investment,

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1. It is reassuring to note that (2.1) - (2.6) imply that the national income identity is observed in the snapshot year. From (2.1) and (2.4) we have

$$P'X = P'C + P'KJ + P'AX ,$$

and

$$P'X = P'AX + W\ell X + rP'KX .$$

i.e.,

$$0 = P'C + P'KJ - WN - rP'KX ,$$

i.e., consumption plus investment expenditure equals wage income plus rentals on capital.

savings, the rate of return, the length of run, what happens in the snapshot period, substitution possibilities, the method for computing solutions and international trade.

(a) Investment

Perhaps the least familiar aspect of Table 2.1 is the treatment of investment. What (2.5) does is to exogenize industry growth rates *in* the snapshot year. It does not exogenize industry growth rates *to* the snapshot year. For example, in section 4 we discuss projections for industry growth rates for the period 1971/72 to 1990/91. The latter year is the snapshot year. Under various assumptions concerning technological and demographic factors in 1990/91 we use the SNAPSHOT model to project industry output levels for 1990/91. Then the growth rates to 1990/91 are computed by comparing industry outputs in 1971/72 with those projected for 1990/91. With a few exceptions these results are insensitive to changes (within reasonable ranges) in the G matrix. That is, SNAPSHOT implies that the growth prospects to 1990/91 for most industries are largely independent of growth in 1990/91. The exceptions are those industries (e.g., construction) whose sales are particularly dependent on investment levels.

Plausible values for G can be obtained by iterating so that growth rates in the snapshot year (1990/91) equal the projected growth rates for the snapshot period (1971/72 - 1990/91). This effectively endogenizes G. We can proceed by guessing G, computing industry outputs in 1990/91 and hence the snapshot period growth rates, resetting G to reflect the growth rates projected for the snapshot period, recomputing the snapshot period growth rates, etc.. We adopted this procedure in the computations reported in section 4. No difficulty was experienced in obtaining convergence. This was to be expected in view of the insensitivity of the industry growth projections to changes in G .

(b) Savings and rates of return

A second aspect of the SNAPSHOT theory which needs amplification is the treatment of savings and rates of return. Will SNAPSHOT imply a plausible savings share (s) in the GDP of the snapshot year or should we exogenize the savings share by adding a suitable savings function to the model? In terms of SDV, the question is whether the model produces plausible values for

$$s = \frac{P'KJ}{WN + rP'K} \qquad (2.9)$$

or whether we should specify s exogenously and include (2.9) as an additional equation. Of course, if we add (2.9), then we must find one more endogenous variable. The obvious candidate is r . We can imagine an iterative procedure for endogenizing r as follows. First we solve the set of equations (2.1) - (2.6) with r set exogenously at $r(1)$. If the implied value for s is too high, then we raise r , i.e., $r(2) > r(1)$ and recompute. Raising r will have the effect of increasing the relative prices of capital intensive goods. Household demand will then be diverted away from these goods causing a reduction in the projected growth rates for capital intensive industries relative to labour intensive industries. With J specified according to (2.5) (with or without iterative adjustment to achieve consistency between snapshot year and snapshot period growth rates), a change of the X vector towards labour intensive goods will reduce the investment and savings requirements for the snapshot year. Similarly, if our initial guess for r caused s to be too low, in subsequent computations we would reduce r, causing s to increase.

In practice we have found that although SNAPSHOT does imply that s is negatively related to r, the elasticity of s with respect to r is close to zero, i.e., s is very insensitive to changes in r. The reasons are (i) that changes in r have only a small impact on relative prices and (ii) that changes in relative prices have only a small impact on consumption patterns. (i) follows from the fact that in the SNAPSHOT data base, the share of costs accounted for by rentals on fixed capital tends to be small and uniform across industries.[1] (ii) is implied by our use of an additive specification for U,[2] which effectively rules out the possibility of large substitution effects.

An implication of the insensitivity of s with respect to r is that it would only be by a lucky chance that SNAPSHOT implied a plausible value for r, given an exogenously specified value for s. For example, assume that we wish to impose the condition that $s = .20$ in the snapshot year. Then we might set r at .12, (say) and find that $s = .25$. To lower s to the exogenously set level (.20) it might be necessary that r be raised to an unrealistically high value such as .4. Consequently, rather than fine tune s by varying

1. For example, in the base year data, the ratio of rentals on fixed capital to total costs averaged .127 across industries with a variance of only .014.

2. SNAPSHOT has 9 consumer groups and the preferences for each are described by log-linear utility functions, see Williams [1978].

r , we have preferred to set r exogenously at values consistent with history and to let s be determined endogenously. As will be seen in section 4, the resulting values for s have been realistic.

In summary, SNAPSHOT appears to have little to say about the determination of rates of return. Therefore we have set them exogenously. On the other hand, s seems to be well explained in SNAPSHOT and therefore we have left it as endogenous.

(c) The length of run

Given the treatment of investment and rates of return, it is apparent that SNAPSHOT is a long-run model. For short-run analysis, it would not be appropriate to set rates of return exogenously or to assume that industry investments in the snapshot year will simply maintain the industry growth rates established over some prior period. The initial effect of the adoption of a technical innovation, for example, might be to increase growth rates and rates of return in the industries that benefit. In the long-run, however, it is reasonable to suppose that investment levels and rates of return would revert to historically typical values.[1] Consequently, SNAPSHOT would be suitable for making projections for (say) 10 years into the future but not for one year.

The long-run nature of the model is further underlined by the treatment of primary factors. In SDV, where there is only one type of labour, there can be no bottlenecks on account of shortages of particular skills. This is also true in SNAPSHOT where there are

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1. As explained in section 2(a), historically typical growth rates can be established endogenously.

nine types of labour. It is assumed that the labour force is sufficiently malleable to meet any set of occupational demands which is consistent with the overall labour availability in the snapshot year. Since this assumption may imply considerable changes in the relative sizes of occupational groups, it is most easily defended for simulations where the snapshot year is sufficiently far into the future for there to be significant entry and retirement from the labour force over the snapshot period. Similarly, SNAPSHOT incorporates no bottlenecks at the industry level in the availability of capital stocks.

(d) What happens in the snapshot period?

From a practical point of view an attractive feature of the snapshot approach is that it avoids the problems[1] of specifying and implementing a fully intertemporal model by simply asking what the economy will look like at a particular point of time in the future. This leaves unanswered questions concerning the path by which the economy reaches the snapshot year and raises some difficulties in interpreting model results.

The most obvious question concerns the feasibility of accumulating physical and human capital at the rates implied by the SNAPSHOT solution. For example, we should check whether the implied rate of accumulation of physical capital is consistent with prospects for domestic savings and capital inflow over the snapshot period. We should also make allowance for capital outflow in the snapshot year associated with interest payments on the capital inflow implied by the model for the snapshot period. However, at the current point of

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1. For a recent study of these problems in the context of a fully intertemporal model of the Australian economy, see Meagher [1978].

our research, we treat capital inflow/outflow in the snapshot year as exogenous.[1] In addition, we can only suggest informal checks on the plausibility of the implied rates of capital accumulation.

A related issue concerns comparisons across SNAPSHOT solutions. Consider a situation in which we have two SNAPSHOT computations whose exogenous inputs differ only with respect to the technology matrices. In the first, real GDP for the snapshot year is 100 while in the second it is 105. Is this evidence that the second set of techniques is superior to the first? Perhaps the reason for the differences in the GDP results is that under the second set of techniques, the SNAPSHOT solution shows the economy to have greater capital stocks and a more skilled labour force in the snapshot year than under the first. Because we abstract from events in the snapshot period, the model fails to account for the costs of the additional capital accumulation and labour training. Thus, the mere comparison of the GDP results is insufficient to establish a preference for one set of techniques over the other. The practical importance of this point is illustrated in section 4.2(a).

(e) Substitution possibilities

The technology matrices (A, K and ℓ) for the snapshot year are exogenous to a SNAPSHOT computation. Consequently, the model fails to account for price induced substitution between alternative inputs to production processes.

In the context of the experiments reported in section 4, one can imagine overcoming this problem by an iterative process. First we would guess a price vector (including commodity and factor prices) for the snapshot year. Then we would ask our industry

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1. More precisely, we set the balance of trade exogenously and ignore changes in international reserves.

experts to forecast the A, K and ℓ matrices for 1990 given our initial guess for the prices. Using these A, K and ℓ matrices, we would compute the implied price vector from the SNAPSHOT model. Then we would return to our industry experts to see if they wished to modify their forecasts of A, K and ℓ in the light of the prices established by the model.

In practice, however, the Bureau of Industry Economics (see section 4.1(a)) reports that the industry experts' forecasts for A, K and ℓ are insensitive to alternative price scenarios for the snapshot year. This is not surprising in view of the failure of numerous studies to establish relative input prices as a major determinant of changes in input-coefficients. For example, Sevaldson [1976] examines a long time series of Norwegian input-output tables. He rejects the idea that changes in techniques are closely related to changes in relative prices. His results imply that attempts to model input substitution in response to changes in relative prices are likely to have only minor payoffs.

(f) The computational approach

The SNAPSHOT model is solved by exploiting the relationship between the solution to an economic model and the solution to a programming problem. The method can be illustrated by reference to SDV. To solve SDV we could proceed as follows. We set up the programming problem :

$$\left.\begin{array}{l} \text{choose } C \text{ and } X \text{, nonnegative,} \\ \text{to maximize } U(C)\text{,} \\ \text{subject to} \\ \qquad X \geq C + rKX + AX + \chi\text{,} \\ \text{and} \quad \ell X \leq N\text{,} \end{array}\right\} \qquad (2.10)$$

where χ is an $n\times 1$ vector of exogenous variables whose role will be explained below. We note that if $(\overline{C}, \overline{X})$ is a solution to (2.10), then there exist $\overline{P}$ and $\overline{W}$, nonnegative, such that $\overline{C}$, $\overline{X}$, $\overline{P}$ and $\overline{W}$ jointly satisfy[1]

$$\left.\begin{array}{rcll} \nabla U(\overline{C}) - \overline{P} & = & 0 & \text{(a)} \\ \overline{P}' - \overline{P}'A - r\overline{P}'K - \overline{W}\ell & = & 0 & \text{(b)} \\ \overline{X} - \overline{C} - rK\overline{X} - A\overline{X} - \chi & = & 0 & \text{(c)} \\ \ell\overline{X} - N & = & 0\ . & \text{(d)} \end{array}\right\} \qquad (2.11)$$

It is apparent that $\{\overline{C}, \overline{P}/\overline{W}, \overline{Y}/\overline{W}, \overline{J}, \overline{X}, 1\}$ solves our economic model (2.1) - (2.6), where $\overline{J}$ is computed as $G\overline{X}$ and $\overline{Y}$ is computed as $\overline{P}'\overline{C}$, provided only that

$$\chi = (KG - rK)\overline{X}\ . \qquad (2.12)$$

(Under (2.12), (2.11)(c) correctly represents the market clearing equation for commodities.)

This suggests an iterative procedure for solving SDV. We guess a value for $\overline{X}$ and compute χ according to (2.12). Next we solve (2.10), both primal and dual. Then we update our guess of $\overline{X}$, etc..

In summary, the SNAPSHOT algorithm requires the solution of a programming problem at each step. The parameters of the programming problem are changed from step to step so that eventually our programming problem correctly reflects features of the economic model such as ad valorem taxes, multiple consumers and exogenously given rates of return. Full details of the computation theory are in Dixon [1976].

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1. It is reasonable to suppose that the first order conditions for (2.10) hold as equalities as represented in (2.11), i.e., for convenience we exclude the possibility of free goods, free labour, satiety, and negative profits at zero output levels.

3. INTERNATIONAL TRADE IN THE SNAPSHOT MODEL

One way of adding international trade to our SDV is as follows. First we modify (2.1) and (2.4) to read

$$X = C + KJ + AX + E - M \tag{3.1}$$

and

$$\left.\begin{aligned} P' &\leq P'A + W\ell + rP'K && \text{(a)} \\ (P' - P'A - W\ell - rP'K)X &= 0 && \text{(b)} \end{aligned}\right\} \quad (3.2)$$

where E and M are vectors of commodity exports and imports. Equation (3.2) allows for the case where some production processes cannot cover their costs with the result that they are operated at the zero level. (If the i^{th} component of (3.2)(a) holds as a strict inequality, then, given the nonnegativity of X, (3.2)(b) implies that $X_i = 0$.) It is necessary to allow for the zero production case because with the inclusion of international trade it is possible that all domestic requirements for good i (say) are satisfied by imports.

At this stage we have added $2n$ variables (E and M) to SDV without changing the effective number of equations. To reclose the model we need to make up the deficit of $2n$ in the number of equations compared with the number of endogenous variables. We start by noting that for commodities which are nontraded, we have

$$\left.\begin{aligned} E_i &= 0 \\ M_i &= 0 \end{aligned}\right\} \; i \in R\,, \tag{3.3}$$

where R is the set of indices for the nontraded commodities. If we denote the number of elements in R by ρ, $\rho < n$, then (3.3) provides 2ρ equations. The closure of the model can now be completed by

$$P_i \leq P_i^m \Theta + \xi_i \qquad \text{(3.4)(a)}$$

$$(P_i - P_i^m \Theta - \xi_i) M_i = 0 \qquad i \notin R , \qquad \text{(3.4)(b)}$$

$$P_i \geq P_i^e \Theta + \phi_i$$

$$(P_i - P_i^e \theta - \phi_i) E_i = 0 \qquad i \notin R , \qquad \text{(3.5)}$$

and

$$\sum_{i \notin R} P_i^e E_i - \sum_{i \notin R} P_i^m M_i = 0 , \qquad \text{(3.6)}$$

where P_i^m and P_i^e are, respectively, the foreign currency costs per unit of imports of good i and the foreign currency revenue per unit of exports of good i , ($P_i^m > P_i^e$ because of transport costs), Θ is the exchange rate ($Domestic/$Foreign) and ξ_i and ϕ_i are the tariffs and export subsidies payable on units of imports and exports. P_i^m , P_i^e , ξ_i and ϕ_i are treated as exogenous.[1] Thus, (3.4) - (3.6) effectively add $2(n-\rho)+1$ equations and one new endogenous variable, Θ .

Equations (3.4) and (3.5) imply that, for traded goods, import prices plus tariffs set ceilings on domestic prices (P) while export prices plus export subsidies set floors.[2] If the domestic price of good i is below the ceiling, then none will be imported and if it is above the floor, then none will be exported. Equation (3.6) sets the balance of trade at zero. Finally, we note that (3.1) - (3.6) imply that

$$P'C + P'KJ = W\ell X + \bar{r}P'KX + \sum_{i \notin R} (\xi_i M_i - \phi_i E_i) ,$$

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1. With P_i^m and P_i^e exogenous, we are adopting the small country assumption.

2. We assume that $P_i^m \Theta + \xi_i \geq P_i^e \Theta + \phi_i$, otherwise infinite profits would be available from importing and re-exporting.

i.e., the model continues to imply that expenditure equals income, where income includes tariff revenue less subsidies.

Many minor modifications of (3.3) - (3.6) are possible. For example, we could modify (3.4) and (3.5) to make the tariffs and subsidies ad valorem rather than specific, we could allow for exports and imports of predominantly nontraded commodities by setting the RHSs of (3.3) exogenously at values other than zero, and we could allow for capital flows by adopting a non-zero exogenous value for the balance of trade. Unfortunately, however, major modifications are required before an empirically satisfactory model which includes international trade is obtained.

The fundamental problem with using (3.1) - (3.6) is that we then have a model which will almost certainly imply unrealistic levels of specialization in production and international trade. Typical solutions will show only one commodity as being exported. Normally there will be no commodity which is both imported and domestically produced and there will be no commodity which is simultaneously imported and exported. Too few of the real-world phenomena which explain diversification in production and trade are modelled. With no terms of trade effects (P^e and P^m are exogenous) and no scarce industry-specific factors (e.g., agricultural land, mines), the model implies that the exports of any particular commodity can be expanded to any extent without penalties either in terms of a reduction in selling price or in terms of an increase in unit production costs relative to those in other potential export industries. With each domestic product modelled as a perfect substitute for the corresponding imported product, imported and domestic products can coexist in the domestic market for good i only in the unlikely circumstances that domestic unit cost (i.e., the i^{th} component of the RHS of (3.2)(a)) precisely equals the import price for good i (i.e., the RHS of (3.4)(a)).

In IMPACT's ORANI model[1] we have included terms of trade effects, industry-specific factors, imperfect substitution between imported and domestic products and various other diversfying phenomena. Consequently, that model does not suffer from the specialization problem. In SNAPSHOT the specialization problem has been avoided simply by specifying that

$$E = \overline{E} \quad , \quad i \notin R \quad , \tag{3.7}$$

and

$$\left.\begin{aligned} M_i &\le \gamma_i X_i & \quad (3.8)(a) \\ (M_i - \gamma_i X_i)\, \xi_i &= 0 & \quad (3.8)(b) \end{aligned}\right\} \; i \notin R \; ,$$

where $\overline{E}$ is a vector of exogenous projections for export levels in the snapshot year and the γ_i's are parameters limiting imports to exogenously given shares of the domestic markets. Notice that under (3.7) and (3.8) we have effectively added $2(n-\rho)$ equations to our model. The corresponding endogenous variables are the tariff rates (ξ_i) and the export subsidies (ϕ_i). Rather than these being exogenous, we now let the model determine their values. The tariff (ξ_i) will be just high enough to ensure that imports of good i satisfy (3.8)(a). If (3.8)(a) were satisfied as a strict inequality then ξ_i would be lowered unless of course it were already at zero. In the case of ϕ_i there is no sign constraint. Exports of commodity i will be sufficiently subsidized $(\phi_i \ge 0)$ or taxed $(\phi_i < 0)$ to achieve the exogenously given level for E_i.

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1. See Dixon, Parmenter, Ryland and Sutton [1977].

One important implication of (3.7) and (3.8) is that they imply that relative domestic prices (P/W) are completely determined by domestic technology (A, K and ℓ) and the rate of return (r).[1] Because (3.7) and (3.8) rule out the possibility of domestic production for any commodity being driven to zero, from (3.2) we can write

$$P' = W\ell \; (I - A - rK)^{-1} \; . \qquad (3.9)$$

Equation (3.9) means that SNAPSHOT projects relative domestic prices for the snapshot year independently of the exogenously given export projections, import share projections and projections for foreign currency prices. We can think of the tariffs (ξ_i) and subsidies (ϕ_i) as playing the role of forcing compatibility in the home market between the exogenously given world prices on the one hand and the continuing existence of the exogenously given domestic technology on the other.

In view of (3.7) and (3.8), it is apparent that trade flows are determined largely exogenously in SNAPSHOT. This, in addition to the exogeneity of technology and demography, mean that SNAPSHOT is better thought of as a tool for consistency checks rather than as a tool for initiating forecasting exercises. From the point of view of creating forecasts, the model leaves the forecaster with too much work (i.e., too much is exogenous). On the other hand, SNAPSHOT is a convenient tool for checking the consistency of forecasts from diverse sources. For example, it is common for experts on particular industries to make industry forecasts on long term export sales, import penetration and technology. With SNAPSHOT, we can check that sets of such forecasts are consistent with the economy-wide balance of trade constraint and

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1. In SNAPSHOT (as distinct from SDV) where there are 9 types of labour, occupational wage relativities also play a role in determining relative prices.

with plausible levels of assistance. Section 4 illustrates the consistency aspect of SNAPSHOT by considering the tensions between a forecast of Australia's technological future provided from one source and a forecast of world commodity prices provided from another.

4. SOME ECONOMIC IMPLICATIONS OF TECHNICAL CHANGE IN AUSTRALIA TO 1990/91 : AN ILLUSTRATIVE APPLICATION OF SNAPSHOT

This section compares two sets of SNAPSHOT results. The first was generated by running the model with the exogenous variables set at forecast values for 1990/91. The results from this simulation could be considered forecasts for that year. Throughout the section, however, we emphasize the tentative and incomplete nature of the forecasts for the exogenous variables. The credibility of the SNAPSHOT forecasts could be greatly enhanced if more resources could be devoted to work on the exogenous variables.

In the second set of simulations, the model was run with the production techniques matrices set at their base period[1] (1971/72) values, while the 1990/91 forecasts were retained for all other exogenous variables. Thus we study an economy which foregoes technical progress for 19 years. The comparison between our two simulations provides a basis for discussing some of the implications of technical progress. Put in frankly emotive terms, the comparison is between the long-term prospects for what we will call an innovative economy and those for what we will call a Luddite economy.

The material is presented in two subsections. In subsection 4.1 we describe how the forecasts were made for the exogenous variables to 1990/91. This subsection is divided into four parts. Part (a)

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1. 1971/72 is the base year in both our simulations. The G matrix (see section 2(a)) was manipulated so that industry growth rates in the snapshot year (1990/91) were compatible with those implied for the snapshot period which was taken to be 1971/72 to 1990/91.

is concerned with forecasting the 1990/91 techniques of production. Part (b) discusses the forecasts of exogenous variables connected with Australia's international trade. Part (c) discusses demographic factors while in part (d) we handle miscellaneous exogenous variables. Simulation results are given in subsection 4.2. In part (a) of that subsection we discuss the implications of technical change for the macro variables (consumption, investment, GDP, average wages, etc.). Then in part (b) we look at projections for industry growth rates for the period 1971/72 to 1990/91. Finally, in part (c), we present labour demand projections by occupation.

4.1 The setting of the exogenous variables for 1990/91

(a) Production techniques for 1990/91 (A, K and ℓ)

The industrial classification for SNAPSHOT is that of the 109-order 1968/69 Australian input-output tables (see ABS [1977]). For the labour coefficients matrix, ℓ , the occupational classification is the 9-order one developed by Tulpulé and McIntosh [1976] for the IMPACT Project. (The industrial and occupational categories can be seen by glancing at Tables 4.3 and 4.1.) Thus, with respect to production techniques, our task is to forecast the two 109 × 109 matrices A and K and the 9 × 109 matrix ℓ to the year 1990/91.

Our approach was to update existing matrices for 1971/72.[1] Two methods were used. First, we applied the results of a study by the Bureau of Industry Economics (BIE). Second, for industries not covered by the BIE study, we made trend projections.

1. The construction of the 1971/72 matrices is described in Harrower and Vincent [1978].

The BIE study is described by Chapman and Wood [1978a, b and c]. Briefly, their work involved interviews with experts from selected industries. Each expert was asked to update his industry's columns in the A , K and ℓ matrices to 1990/91. The experts were supplied with statistical information including the 1971/72 coefficients which they were being asked to project to 1990/91, and a breakdown of their industry to the 4-digit ASIC level. Where available, information was given at this level on the occupational composition of the workforce, wages, materials usage, and output trends. Experts were also given a general (non explicit) macro scenario for 1990/91. They were told to assume that wage costs would continue to rise relative to capital costs, government assistance to investment (depreciation allowances, etc.) would continue as at present, and that there would be relative increases in crude oil and related product prices. Unfortunately, the BIE study covers only 12 industries accounting for about 22 per cent of the GDP in 1971/72. The industries are : iron ore mining, other metallic minerals, coal and crude petroleum, petroleum and coal products, other basic metals, motor vehicles and parts, plastic and related products, motor vehicle repairs, road transport, residential buildings, building and construction and communications. These industries were judged to be ones in which significant technical change is likely to take place.

For the remaining industries we applied trend projections to the columns of ℓ . Rates of productivity growth for the period 1962/63 to 1972/73 were assumed to be maintained to 1990/91 with no change in the occupational composition of the workforce within each industry. No changes were made to the columns of the K matrix and only minor adjustments were made to the A matrix (along the lines set out in Chapman and Wood [1978c]) to account for anticipated changes in the usage of plastic products and communications. Thus, our 1990/91 A and K matrices are substantially the same as those for 1971/72. This is probably reasonable. Where time-series of comparable input-output data are available, it has generally been found that the dominant features of technical change are embodied in the ℓ matrix. (See for example Carter [1970] for the U.S. and Sevaldson [1976] for Norway.)

In Table 4.1 we have computed

$$L000 = \ell_0 (I - A_0)^{-1} Y_0 ,$$

and

$$L110 = \ell_1 (I - A_1)^{-1} Y_0 ,$$

where Y is a vector of final demands and where 0 refers to the base year, 1971/72, and 1 refers to the snapshot year, 1990/91. Thus, for example, Y_0 is the final demand vector for 1971/72. Given the comparatively minor role of changes in K , these computations provide a fairly comprehensive picture of our projections for production techniques. For example, they show that the number of persons required to deliver the 1971/72 vector of final demands is projected to decline by 32 per cent implying an average annual rate of productivity growth for 1971/72 to 1990/91 of 2.0 per cent. The largest reductions in labour requirements are for rural and blue collar workers while the smallest productivity gains are projected for the industries employing the bulk of the white collar workers.

Table 4.1 Labour Requirements by Occupation to Deliver a Fixed Vector of Final Demands Assuming 1971/72 and 1990/91 Production Techniques

Occupation	Labour Requirements (thousands of persons) 1971/72 Techniques	Labour Requirements (thousands of persons) 1990/91 Techniques	Ratio 1990/91 - 1971/72
1. Professional White Collar	173	137	0.79
2. Skilled White Collar	670	496	0.74
3. Semi and Unskilled White Collar	1,412	1,039	0.74
4. Skilled Blue Collar (Metal and Electrical)	570	353	0.62
5. Skilled Blue Collar (Building)	268	159	0.59
6. Skilled Blue Collar (Other)	135	92	0.68
7. Semi and Unskilled Blue Collar	1,678	1,092	0.65
8. Rural Workers	252	138	0.55
9. Armed Services	85	75	0.88
Total	5,243	3,581	0.68

Although these results may seem intuitively plausible, it is clear that not a great deal of credence should be given to our A , K and ℓ projections. Much more work is required. In the case of the trend projections, all that can be said is that the results are conceivable in view of the historical record. In the case of the BIE study, several important problems are left unresolved. First, there is doubt about the extent to which the projections are consistent with the relative price picture that they imply. As explained in section 2 (e), ideally, we should solve the SNAPSHOT model using the experts' initial projections of A , K and ℓ . Then we should return to the experts and ask whether they wish to modify their projections in view of the prices implied by the model for the snapshot year. Chapman and Wood [1978a, p. 9] consider, however, that their forecasts are fairly robust with respect to relative price changes. They doubt the capacity of the experts to assess quantitatively the effects of different relative price scenarios on technical developments.

A second doubt concerns the picture which the industry experts had in mind concerning Australian trade policy. If they envisaged a continuation of high rates of protection, then their projections would probably differ from those appropriate for a more open economy where economies of scale are readily exploitable via export markets. It obviously would be desirable if those making forecasts of techniques were explicitly confronted with the assumed trade situation (i.e., the assumptions concerning export levels, import penetration and the implied levels of protection). Again, in the ideal situation, we can imagine an iterative process involving interaction between the model and the experts.

A third doubt concerns the distinction between Australia-specific and world-wide changes in techniques. It is not clear from the available documentation as to whether the industry experts were asked to make such a distinction. It is, however, an important one for trading industries. The long-term growth prospects of these industries depend on the local rate of technical progress compared with that of similar industries in other countries.

(b) Trading prospects for 1990/91

World prices (P^e, P^m)

The world price vectors $(P^e$ and $P^m)$ for 1990/91 were constructed by applying growth rates to the world price vectors for 1971/72. That is, they were computed from

$$\frac{P_i^e(1990/91)}{P_i^e(1971/72)} = \frac{P_i^m(1990/91)}{P_i^m(1971/72)} = (1 + g_i^w)^{19}, \text{ for all } i , \quad (4.1)$$

where g_i^w is the rate of growth in the world price for good i over the period 1971/72 to 1990/91 and $P_i^e(1971/72)$ and $P_i^m(1971/72)$ were obtained from the base period data.[1]

The g_i^w's are listed in column V of Table 4.3. In formulating them we relied heavily on an IMPACT commissioned study (Freebairn [1978]) of likely developments affecting demands, supplies and prices of internationally traded commodities in the long term. Underlying Freebairn's work are assumptions about long-term rates of growth of income and population (on the demand side), and rates of technical change and investment (on the supply side) together with estimates of world price elasticities of supply and demand. The likely effects of commodity cartels, particularly for oil, are also considered. The general features of the resulting projections for world prices are as follows. Prices of machinery, equipment, appliances and motor vehicles are projected to rise most slowly. This reflects an anticipation that for these commodities technical innovation and the adoption of more capital intensive production techniques will continue

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1. See Harrower and Vincent [1978] or Dixon, Harrower and Vincent [1978, p.27].

at a rapid rate. The next slowest-to-rise group (price increases around 2.6 per cent per year faster than the first group) consists mainly of products produced by (or anticipated to be soon produced by) less developed countries. Included here are steel and most metal products that are not highly fabricated. The fastest rising prices are for meat products (especially beef), fishing exports (which consist largely of luxury items such as lobsters and prawns) and advanced country exports (other than machinery). Also included here are wool, dairy products and oil. These prices are assumed to inflate from 4-5 per cent per year faster than those of the slowest increasing group. Of the remaining agricultural commodities, the prices of wheat and sugar are projected to increase by 2.8 and 2.6 per cent respectively relative to the slowest increasing group. In total, these price projections imply an improvement in Australia's terms of trade of about one per cent per year over the period 1971/72 to 1990/91.

Export quantities ($\bar{E}$)

For projection purposes we divide the export vector into the following categories :

(i) agricultural products, processed and unprocessed,

(ii) minerals, processed and unprocessed,

and

(iii) non resource based manufacturing products.

Agricultural and mineral products contributed 79 per cent of base year exports. Australia's comparative advantage in these products stems from natural endowments such as favourable land and climate (in the case of (i)) and easily accessible mineral deposits (in the case of (ii)). We would expect, therefore, that this comparative advantage would continue. In fact our projections imply that agricultural and mineral products will account for 89 per cent of the value of exports in 1990/91 with the volume of agricultural exports achieving an average growth rate of 2.7 per cent over the period 1971/72 to 1990/91 while the corresponding figure for mineral exports is 5.5 per cent. Growth rates as high as these seem reasonable in view of our favourable projections of world price developments for these sectors. However, as is explained below, we expect that continued rapid growth (from a small base) in the volume of exports of manufactured commodities will limit the growth in the share of agriculture and mining in the value of total exports.

Within Australia's agricultural sector, there are extensive transformation possibilities between products.[1] Since our world price projections imply an increase in the prices of wool and beef relative to wheat, we would expect a shift in the commodity mix of Australia's agricultural exports away from wheat. To help quantify this effect, we ran the ORANI model[2] in long-term mode under the same world price and demographic scenarios as were used in the present SNAPSHOT application. While exports and imports are handled endogenously in ORANI, the currently operational version of that model does not allow for technical change. Therefore, before using the ORANI results on agricultural exports as the basis for

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

2. The latest version of ORANI includes estimates of transformation possibilities between major products within agriculture, see Dixon, Parmenter, Powell and Vincent [1979]. For minor agricultural products our projections are based on studies by the Bureau of Agricultural Economics. See, for example, Hussey [1979].

the projections to be supplied to SNAPSHOT, we modified them to allow for outward shifts (of the order of 2 per cent)[1] in agricultural production functions.

Our projections for mineral exports rely on detailed work by Smith [1978]. Smith's analysis includes consideration of world demand, the availability of alternative supplies, the anticipated future competitiveness of Australian processing and features of international markets.

In comparison with our projections of export prospects for agriculture and mining, our projections for non-resource based manufacturing commodities must be even more speculative. Factor endowments in the production of these commodities are less readily identifiable and therefore the basis for long-run comparative advantage is less clear. A study by G. Dixon and McGowan [1979] showed that despite apparent cost disadvantages, Australian export growth rates have been high (greater than world trade growth rates) for a number of manufactured goods over the 1968/69 to 1976/77 period.[2] Their analysis suggests that export growth has been positively related to human capital intensity in the production process. Support for the importance of supply side factors such as skill intensity is also provided by Kasper and McMahon [1976] and Duncan [1978]. We relate export growth prospects for most manufacturing industries to an indicator of industry skill intensity in the snapshot year. The indicator is constructed by weighting normalised labour coefficients

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1. This figure for the rate of technical progress in agriculture is consistent with the findings of Young [1971], for example.

2. In many instances, however, these growth rates occurred from a very small base.

for 1990/91 by the 1971/72 vector of relative wages. In view of the high export growth rates exhibited by manufacturing industries in recent years, comparatively high rates of 8, 6 and 4 per cent per year were assigned to such industries according to whether their skill intensities were classified as being high, medium or low respectively.

Import shares (γ)

Our starting point is the vector of base year import shares. Rather than attempt at the outset to project changes in import penetration in particular industries, we proceed as follows. First, we run the model with the appropriate technology, demography and trade scenarios and the vector of base year import shares. The outcome, in all experiments conducted in this paper, is a surplus of foreign exchange (foreign currency value of exports exceeds the foreign currency value of imports). (This outcome ensues from our favourable export scenario which is held constant across experiments.) We then multiply the vector of import shares by a scale factor such that in a second run of the model, the foreign currency value of imports is just sufficient to balance the exogenously specified foreign currency value of exports. In terms of section 3, our approach is to replace (3.6) and (3.8)(a) by

$$\sum_i P_i^e E_i - \sum_i P_i^m M_i \geq 0 , \qquad (4.2)$$

and

$$M_i \leq \alpha\gamma_i(1971/72)\ X_i, \text{ for all } i , \qquad (4.3)$$

where α is initially set at 1 and is then increased until (4.2) holds as an equality.

(c) Demographic factors : the size of the workforce and household preferences (N and U)

The National Population Inquiry [1975] (the Borrie Report) projects a population of 16.1 million in 1991 (assuming net immigration of 50,000 per year) and a workforce participation rate of 49.2 per cent. This gives a workforce of 7.9 million in 1990/91 and we assumed that this would be the number of people employed.

The specification of household preferences in SNAPSHOT is based on work by Williams [1978]. Williams estimated the parameters of log-linear utility functions describing the preferences for nine socio-economic groups identified in the ABS [1977-8] Household Expenditure Survey for 1974/75. These utility functions were, in effect, aggregated into an aggregate household utility function (U) by using the joint maximization method described in Dixon [1976]. The weight of each group's preferences in the aggregate preferences depends on the group's share in total household expenditure in 1990/91. These shares were projected by taking into account likely changes in the number of households in each group.[1] For example, on the basis of the Borrie Report we can conclude that there will be a more rapid increase in the number of households where the 'head' is over 65 years than in the number of households with three or more dependent children, etc..[2]

(d) Miscellaneous exogenous variables

Readers who are familiar with SNAPSHOT (as distinct from SDV) will recall that the model contains many more exogenous variables

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1. We assumed fixed relativities across groups in the average expenditure levels. That is, if in the base period the average household in group I had twice the expenditure level of the average household in group II, we assumed that this would continue to be true in 1990/91.

2. Details of the projection method for the group shares in aggregate household expenditure are in Vincent [1979].

than those considered so far. These include various tax rates, depreciation rates, occupational wage relativities, rates of return for each industry and government expenditure. With the exception of the last mentioned, we assumed that these variables maintained their base period (1971/72) values in 1990/91, i.e., we set these variables as in Dixon, Harrower and Vincent [1978]. For government expenditure (classified by input-output categories) we started by assuming that growth rates established over 1962/63 to 1971/72 would be maintained until 1990/91. We then modified the resulting projections in an attempt to make allowance for likely demographic influences on the allocation of government expenditure across such functions as health and education. Details are in Vincent and Granek [1977].

4.2 The simulation results

(a) Macro results

Table 4.2 sets out the basic macro projections. The results in column III were obtained from SNAPSHOT with the exogenous variables set as described in subsection 4.1. Those in column IV are for the Luddite economy in which there is no technical progress in the period 1971/72 to 1990/91. Table 4.2 also contains actual 1971/72 data and the results of a validation experiment. The validation experiment is fully described in Dixon, Harrower and Vincent [1978]. Very briefly, SNAPSHOT's exogenous variables were set at the actual values for 1971/72. The iterative procedure described in section 2(a) was used to force growth rates (the G matrix) in the SNAPSHOT year

Table 4.2 Projections of GDP and Other Macro Variables : Experiments with and without Technical Progress

	I Actual 1971/72	II Validation Experiment[h]	III 1990/91 Innovative Economy [i]	IV 1990/91 Luddite Economy[i]
Consumption[a]	20.9	21.1	52.6 (5.0)	35.8 (2.9)
Gross private investment [a]	9.4	9.2	15.5 (2.7)	8.6 (-0.5)
Government expenditure[a]	4.9	4.9[g]	11.8[g] (4.7)	11.8[g] (4.7)
Exports[a]	5.4	5.4[g]	12.4[g] (4.5)	12.4[g] (4.5)
Imports[a]	-5.0	-5.0	-15.4[f] (6.1)	-15.1[f] (6.0)
Real GDP[a][b]	36.1	35.6	76.9 (4.1)	53.5 (2.1)
Average wage[c] ($ 1971/72)	4237	4220	6063 (1.9)	4096 (-0.2)
Workforce[d]	5.2	5.2[g]	7.9[g] (2.2)	7.9[g] (2.2)
Real productivity[c][e]	6942	6846	9734 (1.8)	6772 (-0.1)

(a) Valued in billions (10^9) of 1971/72 dollars.

(b) Calculated by adding previous items in the column.

(c) Valued in 1971/72 dollars.

(d) Units are millions of people. The rate of growth of the workforce is projected to be considerably higher than that of the population, with workforce participation increasing from about 42 per cent in 1971/72 to about 49 per cent in 1990/91.

(e) Calculated as real GDP divided by the number of people in the workforce.

(f) Trade was assumed to be balanced in 1990/91 on foreign exchange account, i.e., foreign exchange value of exports equals foreign exchange cost of imports. In this table, however, imports and exports are valued at 1971/72 domestic prices. Valued this way, imports exceed exports in 1990/91 because of tariffs in the base year and favourable terms of trade movements over 1971/72 to 1990/91.

(g) These projections are exogenous to SNAPSHOT.

(h) These computations were made by asking SNAPSHOT to project the 1971/72 economy from the base year 1962/63. All exogenous variables were set at their actual 1971/72 values. Full details of the validation experiment are in Dixon, Harrower and Vincent [1978].

(i) Annual percentage growth rates calculated by comparing the 1990/91 figure with the actual 1971/72 figure are shown in parentheses.

to be consistent with growth rates implied by the model for the period 1962/63 to 1971/72. The model gave a very accurate reproduction of the 1971/72 economy, not only at the macro level as shown in Table 4.2, but also for output by industry, employment by occupation and numerous other endogenous variables. This performance is not surprising in a model where so much is taken as exogenous. Nevertheless, it provides reassuring evidence that model misspecification is unlikely to be a source of significant projection errors.

The most obvious feature of the macro results is that the Luddite economy (LE) of 1990/91 is very much poorer than the innovative economy (IE). Without technical change, GDP and real wages are both reduced by about one third. By assumption, however, aggregate employment is maintained. This may be an overly generous assumption for the LE. We would expect the maintenance of employment levels to be much more difficult in a situation of no growth in the level of real wages consistent with full employment. Notice that if we take the path to the LE, then real wage rates are projected to fall at the rate of 0.2 per cent per year whereas the path to the IE gives a growth in real wage rates of 1.9 per cent per year.

Despite the lack of growth in real wages, the LE would imply an increase in material standards of living over the levels of 1971/72. First, the workforce participation rate is projected to be nearly 16 per cent higher. Given the almost static level of workforce productivity, output per head of population would be about 16 per cent higher. Second, compared with 1971/72, the LE devotes a smaller proportion of its resources to gross private investment

(16 per cent of GDP compared with 26 per cent). Consequently, consumption growth and growth in government expenditure considerably exceed the growth in GDP. The state of the 1971/72 economy was consistent with a long-term rate of growth in GDP of about 5½ per cent. (This was the rate achieved over the period 1962/63 to 1971/72.) The LE, on the other hand, can be thought of as a point on a much slower growth path -- a path in which GDP grows at 2.1 per cent per year. A minor compensation for a reduced rate of growth is a reduced need to devote resources to capital formation.

The investment share in the GDP of the IE is also reduced from that in 1971/72 (20 per cent compared with 26 per cent). Again, the principal[1] explanation is the reduction in the rate of growth in GDP over the period 1971/72 to 1990/91 relative to that of the earlier period. Compared with the sixties, the path to 1990/91 for the IE implies both a lower rate of growth of the workforce (2.2 per cent per year versus 2.7 per cent) and a lower rate of growth in labour productivity (1.8 per cent versus 2.8 per cent). While the reduction in the rate of growth of the workforce is readily understandable in terms of well analysed demographic phenomena,[2] the reduction in the rate of growth of labour productivity requires further comment.

It will be recalled from section 4.1(a) that we obtained much of the 1990/91 labour coefficients matrix, ℓ , by assuming that

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1. Another minor factor in explaining the reductions in the investment shares of GDP in both the IE and the LE is a slight switch away from capital intensive industries.

2. See the National Population Inquiry [1975] (the Borrie Report).

trends established from 1962/63 to 1971/72 would be continued to 1990/91. In addition, we assumed that the 1990/91 A and K matrices are very similar to those for 1971/72. The reduction in the economy-wide rate of growth of labour productivity is explained by changes in the growth rates of output for particular industries. The sixties were characterised by exceptionally rapid growth in the mining industries. These industries have very high output per worker based on very high capital intensity. For the period 1971/72 to 1990/91 we project reduced rates of growth in mining activity. Thus, we generate reduced growth in overall labour productivity without necessarily implying a reduction in the rate of growth of labour productivity in any individual industry. We should be cautious, however, about drawing conclusions from this result. It does not mean, for example, that the rate of growth of material standards of living will necessarily decline because of a reduction in the growth of capital intensive industries. As was explained in section 2(d), in its present form SNAPSHOT does not account for the costs of capital accumulation. It does not allow us to compute the level of income accruing to domestic residents.

There is one other slightly paradoxical result concerning labour productivity which is worth mentioning. In Table 4.1 we calculated that the move from the 1971/72 techniques to those of the IE of 1990/91 would reduce the labour requirements to deliver a fixed vector of final demands by 32 per cent implying a 2.0 per cent rate of growth in productivity. Yet the projections in table 4.2 show only a 1.8 per cent rate of growth of productivity. The discrepancy is caused by a small shift in the industrial composition of the economy away from capital-intensive, high-productivity activities.

For example, we notice that government expenditure (which involves labour intensive activities) has a higher share of GDP in the IE of 1990/91 than was the case in 1971/72. Again, we should not draw any conclusions about domestic material welfare.

(b) <u>Industry results</u>

Because of the tentative and incomplete nature of the scenarios on which the projections are based, our emphasis is on the broad features of the results rather than on the results for specific industries. Nevertheless, it will help our discussion of these broad features for readers to have the detailed industry results available. These are presented in Table 4.3.

We start our discussion with the industry growth rates for the period 1971/72 to 1990/91 for the LE (see column II in Table 4.3). The outstanding feature of these results is the poor performance of the import competing industries, e.g., industries 13, 18, 25, 28, 29, 37, 41, 47, 52, 54, 55, 59, 64, 65, 68, 69, 70, 72, 74 and 75. Each of these industries had a high import share in 1971/72 and each is projected to suffer a decline in output over the path to the LE of 1990/91. The only other industries with negative growth rates are 60 (Basic iron and steel) and 62 (Structural metal), both of whose fates are closely connected with that of the import competing industry 65 (Motor vehicles and parts). What has happened in the LE of 1990/91 compared with 1971/72 is that there has been a dramatic increase in import penetration. In fact, with reference to equation (4.3),

$$\alpha^{(LE)}_{1990/91} = 3.15 \quad .$$

Table 4.3 Industry Growth Rates and Price and Labour Productivity Comparisons

		I	II	III	IV	V
I-O	INDUSTRY	Industry Growth Rates, Innovative Economy (% per year)	Industry Growth Rates, Luddite Economy (% per year)	Domestic Costs for the Innovative Economy compared with World Prices (a)	Ratio of Labour Productivity (direct & indirect) in the IE of 1990/91 to that in 1971/72 (b)	Growth Rates in World Prices (p_i^W) (% per year) (d)
1	Sheep	3.56	3.19	- .78	1.82	2.00
2	Cereal Grains	3.16	2.65	.03	1.78	0.00
3	Meat Cattle	3.95	3.25	- .12	1.77	0.00
4	Milk Cattle	2.99	2.10	- .05	1.77	0.00
5	Poultry	3.34	2.29	- .03	1.65	0.00
6	Other Farming	2.64	0.46	- .15	1.82	0.00
7	Services to Agriculture	3.23	2.24	(c)		
8	Forestry	2.59	0.35	- .04	1.74	0.00
9	Fishing	2.38	1.28	- .60	1.79	2.00
10	Iron	3.31	2.80	- .01	1.20	0.60
11	Other Metallic Mins	5.67	4.30	- .45	2.37	0.60
12	Coal & Crude Oil	5.35	2.91	- .05	2.15	2.00
13	Non-Metallic NEC	2.85	- 0.57	- .73	3.09	0.60
14	Services to Mining	3.77	3.62	(c)		
15	Meat Products	3.99	3.30	- .81	1.58	2.40
16	Milk Products	2.63	1.37	- .42	1.57	1.20
17	Fruit & Veg Products	2.58	0.76	.05	1.53	0.00
18	Marge, Oils & Fats	2.34	- 0.65	- .36	1.50	1.00
19	Flour & Cereal Products	2.61	1.38	.06	1.58	0.00
20	Bread, Cakes	2.97	1.47	- .27	1.46	1.00
21	Confectionery	2.50	0.34	.16	1.48	- 0.13
22	Food Products NEC	1.88	0.13	.08	1.56	- 0.13
23	Soft Drinks, Cordials	3.04	1.69	.08	1.51	0.00
24	Beer & Malt	4.78	3.13	.05	1.56	0.00
25	Alcoholic Drinks NEC	3.18	- 0.96	- .35	1.54	1.00
26	Tobacco	4.09	1.42	- .38	1.57	1.00
27	Prepared Fibres	3.46	0.66	- .61	1.72	1.50
28	Man-Made Fibres, Yarn	2.92	- 3.40	- .67	1.78	1.50
29	Cotton, Silk, Flax	3.62	- 2.20	- .06	1.76	- 0.20
30	Wool & Worsted Yarns	4.76	0.91	- .64	1.75	1.50
31	Textile Finishing	5.83	1.89	- .08	1.79	- 0.20
32	Textile Floor Covers	4.90	0.98	- .06	1.75	- 0.20
33	Textile Products NEC	3.46	0.10	- .10	1.75	- 0.20
34	Knitting Mills	5.06	1.39	- .07	1.76	- 0.20
35	Clothing	5.17	1.62	- .08	1.76	- 0.20
36	Footwear	5.02	0.99	- .15	1.82	- 0.20
37	Sawmill Products	2.17	- 0.85	.15	1.55	- 0.20
38	Plywood, Veneers	4.10	0.36	.16	1.54	- 0.20
39	Joinery & Wood Products	4.16	0.80	.16	1.54	- 0.20
40	Furniture, Mattresses	5.63	2.77	.14	1.56	- 0.20
41	Pulp, Paper	2.93	- 1.92	- .62	1.78	1.50
42	Fibreboard	3.53	1.08	- .65	1.78	1.50
43	Paper Products NEC	4.16	1.56	- .60	1.71	1.50
44	Newspapers & Books	4.61	1.45	- .68	1.79	1.50
45	Commercial Printing	4.26	1.92	- .65	1.75	1.50
46	Chemical Fertilisers	3.13	1.69	- .78	1.81	1.50
47	Industrial Chemicals	4.02	- 1.88	- .72	1.98	1.50
48	Paints, Varnishes	3.64	0.36	- .73	1.93	1.50
49	Pharmaceuticals	3.29	1.06	- .74	1.92	1.50
50	Soap & Detergents	5.29	2.81	- .71	1.86	1.50
51	Cosmetics, Toiletry	5.29	2.59	- .71	1.89	1.50
52	Chemical Products NEC	3.67	- 0.61	- .76	2.00	1.50
53	Oil & Coal Products	3.96	0.97	- .27	1.84	2.00
54	Glass	3.75	- 0.74	- .23	2.09	- 0.20
55	Clay Products	3.48	- 0.47	- .20	2.16	- 0.20
56	Cement	3.25	0.76	- .04	2.09	- 0.20
57	Ready-Mixed Concrete	2.20	0.56	- .16	1.95	0.00
58	Concrete Products	4.66	0.75	- .29	2.08	0.00
59	Non-Metal Min Products	3.61	- 0.38	- .20	2.06	- 0.20
60	Basic Iron & Steel	2.55	- 1.12	- .12	2.08	- 0.20
61	Other Basic Metals	5.92	4.62	.40	1.68	- 0.20
62	Structural Metal	3.41	- 0.29	.02	1.72	- 0.20
63	Sheet Metal Products	3.25	0.67	.02	1.73	- 0.20
64	Metal Products NEC	3.48	- 0.53	.05	1.69	- 0.20
65	Motor Vehicles, Parts	3.11	- 0.49	1.81	1.46	- 2.80
66	Ship & Boat Building	2.91	0.68	1.53	1.65	- 2.80
67	Locomotives	4.54	2.09	1.50	1.67	- 2.80
68	Aircraft Building	1.34	- 2.23	1.53	1.66	- 2.80
69	Scientific Equipment	3.61	- 1.79	1.57	1.64	- 2.80
70	Electronic Equipment	2.82	- 0.66	1.55	1.66	- 2.80
71	Household Appliances	4.82	1.05	1.53	1.67	- 2.80
72	Electrical Machinery	3.36	- 1.25	1.62	1.67	- 2.80
73	Agricultural Machinery	4.60	1.36	1.50	1.67	- 2.80
74	Construction Equipment	2.83	- 2.37	1.52	1.68	- 2.80
75	Other Machinery	2.36	- 2.57	1.52	1.68	- 2.80
76	Leather Products	6.11	0.57	- 1.11	2.50	2.10
77	Rubber Products	3.38	0.22	- .61	2.76	- 0.20

continued/-

Table 4.3 (contd)

I-O	INDUSTRY	I Industry Growth Rates, Innovative Economy (% per year)	II Industry Growth Rates, Luddite Economy (% per year)	III Domestic Costs for the Innovative Economy compared with World Prices(a)	IV Ratio of Labour Productivity (direct & indirect) in the IE of 1990/91 to that in 1971/72(b)	V Growth Rates in World Prices (g^W) (% per year)(d)
78	Plastic Products	7.49	0.02	.07	1.69	- 0.20
79	Signs, Writing Equipment	3.65	0.67	- 1.04	2.72	1.50
80	Other Manufacturing	5.43	1.26	- .54	2.67	- 0.20
81	Electricity	4.44	2.49	(c)		
82	Gas	4.64	2.59	(c)		
83	Water, Sewerage	4.83	3.34	(c)		
84	Residential Building	3.91	1.18	(c)		
85	Building NEC	2.84	0.31	(c)		
86	Wholesale Trade	3.97	1.90	.17	1.44	0.00
87	Retail Trade	4.90	2.68	(c)		
88	Motor Vehicle Repair	4.50	2.88	(c)		
89	Other Repairs	5.26	2.91	(c)		
90	Road Transport	3.97	2.19	.17	1.38	0.00
91	Railway Transport	4.66	2.97	- .25	1.90	0.00
92	Water Transport	3.26	1.10	- .28	1.86	0.00
93	Air Transport	3.18	0.39	- .36	1.83	0.00
94	Communication	5.96	2.64	- 1.00	2.89	0.00
95	Banking	4.12	2.25	(c)		
96	Finance & Life Insurance	4.41	2.57	.42	1.16	0.00
97	Other Insurance	4.34	2.39	.43	1.20	0.00
98	Investment, Real Est.	3.95	1.27	.33	1.24	0.00
99	Other Business Services	3.79	1.57	.38	1.26	0.00
100	Ownership of Dwelling	4.83	2.92	(c)		
101	Public Administration	5.64	5.53	.61	1.20	0.00
102	Defence	2.79	2.79	.42	1.25	0.00
103	Health	4.76	4.13	(c)		
104	Education, Libraries	3.91	3.40	(c)		
105	Welfare Services	5.67	4.67	(c)		
106	Entertainment	5.33	2.65	.38	1.26	0.00
107	Restaurants, Hotels	5.62	3.24	.53	1.20	0.00
108	Personal Services	6.30	3.65	.44	1.25	0.00
109	Business Expenses	4.33	1.97	- .04	1.53	0.00

(a) Computed according to equation (4.5), p.48.

(b) Calculated as $\bar{w}\ell_{71/72}\ (I-A_{71/72})^{-1} \big/ \bar{w}\ell_{90/91}\ (I-A_{90/91})^{-1}$, where $\bar{w}$ is a 1 × 9 vector reflecting occupational wage relativities.

(c) Industries producing non-traded goods.

(d) Only relative prices play a role in SNAPSHOT. We have normalized our world price projections so that the average growth rate is zero.

That is, the upper limits on the import-domestic ratios had to be more than tripled before the LE was able to completely spend its foreign exchange earnings. For the IE,

$$\alpha^{(IE)}_{1990/91} = 1.53 \quad .$$

Because of the superior growth performance of the IE, the import shares (associated with the spending of a fixed export revenue) are less than half those in the LE.[1]

The role of the base period import shares (the γ's for 1971/72) and various other factors in determining SNAPSHOT industry projections can be illustrated by running descriptive regressions on the results in columns I and II in Table 4.3. For the LE, we fitted the regression

$$h_i(LE) = \alpha_0 + \alpha_1(EXPDEP)_i + \alpha_2(GOVDEP)_i + \alpha_3(CONDEP)_i + \alpha_4(IMPCOM)_i + e_i \,, \qquad (4.4)$$

$$i=1,\ldots,109 \quad ,$$

where the α_i's are regression coefficients, $h_i(LE)$ is the projected rate of growth for industry i on the path to the LE (e.g., $h_1(LE) = 3.19$) , e_i is the error term, and $(EXPDEP)_i$, $(GOVDEP)_i$, $(CONDEP)_i$ and $(IMPCOM)_i$ are variables measuring industry i's direct and indirect dependence on export sales, sales to government, sales to consumption and the degree to which industry i is subject

1. GDP in the IE of 1990/91 is 3/2 times that in the LE. However, the import shares (the γ's) in the LE are more than 3/2 times those in the IE because the share of the import competing industries in the GDP of the LE is less than the share in the IE.

to import competition. More specifically,

$$(EXPDEP)_i = \beta_i^E g_i^E + \sum_{j \neq i} \beta_{ij} \beta_j^E g_j^E ,$$

$$(GOVDEP)_i = \beta_i^G g_i^G + \sum_{j \neq i} \beta_{ij} \beta_j^G g_j^G ,$$

$$(CONDEP)_i = \beta_i^C \varepsilon_i^C + \sum_{j \neq i} \beta_{ij} \beta_j^C \varepsilon_j^C ,$$

and

$$(IMPCOM)_i = \gamma_i + \sum_{j \neq i} \beta_{ij} \gamma_j ,$$

where β_i^E , β_i^G , β_i^C and β_{ij} are the 1971/72 shares in industry i's total sales accounted for by exports, sales to the government, sales to households and sales to industry j . g_j^E and g_j^G are the exogenously specified growth rates in the exports of good j and government consumption of good j . ε_j^C is the household sector's expenditure elasticity of demand for good j and γ_i is the 1971/72 ratio of imports of good i to domestic output. Thus, each of the variables is a sum of a direct contribution (e.g., $\beta_i^E g_i^E$ is the direct contribution of the growth in i's export sales to the industry's overall growth) and a first-round indirect contribution (e.g., $\sum_{j \neq i} \beta_{ij} \beta_j^E g_j^E$ is the first-round indirect contribution to i's overall growth made by the export growth outside industry i).

The expected signs for α_1 , α_2 and α_3 are positive, while for α_4 we anticipate a negative sign. We would expect industry i's growth rate to be higher if the industry is connected with the fast growing export industries or is a supplier to the government. In view of the increase in per capita income associated with increased workforce participation, we would also expect relatively high growth rates for industries producing expenditure elastic commodities (i.e., commodities with high ε_i's). On the other hand, the projected growth prospects for industries with high base period import shares will be reduced because of our assumption of uniform across-industry percentage increases in import penetration. In the event, we obtained the results shown in the left half of Table 4.4. The right half gives results for a similar regression for the IE economy where the LHS of (4.4) was replaced by $h_i(IE)$. In Table 4.5 we have used the regression results in analyses of the variance in each of the series $h_i(LE)$ and $h_i(IE)$.

From Table 4.4 we see that all the regression coefficients have the expected signs. The results also confirm the dominant role of import penetration in explaining the projections for the LE. Notice from Table 4.5 that 53 per cent of the variation across the $h_i(LE)$'s is associated with variations in the import competition variable, IMPCOM . By contrast, in the fast growing IE economy, variations in growth performance across industries depend more on variations in CONDEP . In a strong growth environment, industries producing expenditure-elastic commodities will be particularly favoured. It is also worth pointing out that in the IE economy, the variables EXPDEP and GOVDEP lose much of their explanatory power with respect to variations across industry growth rates. Unlike the LE, in the IE the rates of growth of exports and government expenditure are not out of line with those of the economy as a whole.

In summary, the present set of SNAPSHOT projections emphasize the importance of rapid growth and technical progress for

Table 4.4 Descriptive Regressions on Industry Growth Results

Variable	Luddite Economy coefficient ($\hat{\alpha}$)	Luddite Economy t-statistic	Technically Innovative Economy coefficient ($\hat{\alpha}$)	Technically Innovative Economy t-statistic
Constant	0.008	5.75	0.032	18.01
EXPDEP	0.834	9.37	0.317	2.94
GOVDEP	0.850	9.01	0.319	2.79
CONDEP	0.012	7.56	0.013	6.97
IMPCOM	-0.041	-17.48	-0.009	-3.21

Table 4.5 Decomposition of the Variance Across Industry Growth Rates[(a)]

Component	Luddite Economy	Technically Innovative Economy
$\hat{\alpha}_1^2$ var(EXPDEP)/var(h)	0.17	0.06
$\hat{\alpha}_2^2$ var(GOVDEP)/var(h)	0.15	0.05
$\hat{\alpha}_3^2$ var(CONDEP)/var(h)	0.11	0.31
$\hat{\alpha}_4^2$ var(IMPCOM)/var(h)	0.53	0.06
covariance terms[(b)]	-0.14	-0.11
R^2	0.82	0.37
var(ε)/var(h)	0.18	0.63

(a) Recall that if we regress y on $x(1), x(2),\ldots,x(n)$ then

$$\text{var}(y) = \sum_k \hat{\alpha}_k^2 \,\text{var}\big(x(k)\big) + 2\sum_k \sum_{j>k} \alpha_k \,\alpha_j \,\text{cov}\big(x(k), x(j)\big) + \text{var}(\varepsilon) \quad .$$

If the covariance terms are small, then we can say that $\hat{\alpha}_k^2$ var(x(k))/var(y) reflects the share of the variance in y which is associated with or explained by variations in $x(k)$. Further details are given in DPRS, pp. 244-5.

(b) The covariance terms are small. In both columns, the largest absolute value over k and j for $2\hat{\alpha}_k \hat{\alpha}_j$ cov(x(k), x(j)) is 0.07.

import competing industries and industries producing expenditure elastic commodities. However, in interpreting the projections, especially those for the import competing industries, we should keep in mind that exports are assumed to be the same in both the IE and the LE. A lack of technical progress will, in general, have adverse effects on the whole of the traded-goods sector. Without technical progress, domestic production costs will increase relative to world prices, hurting both import competing and export industries. To the extent that exports are reduced, this will result in less import penetration. Thus, because our SNAPSHOT results understate the adverse effects on export industries of foregoing technical change, they overstate the adverse effects on the import competing industries. We hope to resolve this problem by using the ORANI model where both imports and exports are endogenous. ORANI currently is being modified to accept scenarios on technical change.

In the meantime, we have supplemented the SNAPSHOT industry output projections with the computations shown in column III of Table 4.3. The figures in column III compare domestic unit costs in each industry in the IE of 1990/91 with the world prices. They were calculated according to the formula

$$\text{Dev(Dom. Costs, World Prices)}_i = \left(\frac{1 + g_i^d}{1 + g_i^w}\right)^{19} - \text{Av}_i\left(\frac{1 + g_i^d}{1 + g_i^w}\right)^{19}, \quad (4.5)$$

i=traded good industry ,

where g_i^d and g_i^w are the rates of growth of domestic and world prices for commodity i over the period 1971/72 to 1990/91 and

Av_i denotes the operation of taking a mean over all values of i . It will be recalled from equation (3.9) that in SNAPSHOT the relativities between domestic prices (costs) depend entirely[1] on domestic technology. Thus, the computations in column III give an indication of which industries are likely to be placed under pressure because of deviations in relative rates of domestic technical progress from those occurring in the rest of the world. For example, according to column III, our scenarios on future production techniques and world prices, imply that industry 65 (Motor vehicles and parts) will be placed in a particularly weak position relative to other Australian traded goods industries. The ratio of unit costs of Australian vehicles to world prices for vehicles is projected to inflate much more quickly than this ratio for most other products. As is apparent from column IV in Table 4.3, growth in domestic labour productivity in industry 65 is projected to be only about average. At the same time, world prices of vehicles are in the slowest growing group, (see column V of Table 4.3). Hence, our scenarios imply that industry 65 will not be particularly innovative in the domestic economy while in the rest of the world, costs will be falling rapidly. If this is to be believed, then we might doubt the ability of industry 65 to sustain the 3.11 per cent growth rate projected for it in the IE. In other words, we might suspect that the proportionate increase in the import penetration ratio for vehicles (γ_{65}) would exceed the average proportionate increase in the γ_i's for the rest of the economy. Before drawing such a conclusion, however, it would be interesting to use the figures in column III to confront our world price and technology experts.

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1. There is one very minor qualification. Because non-competing imports are not produced domestically, their domestic price and the prices of products for which non-competing imports are direct or indirect inputs, can be affected by changes in the exchange rate and the world price of non-competitive imports.

For example, we could ask them whether they saw a contradiction between the world price and productivity forecasts for vehicles or whether they were satisfied with the implication that the Australian industry will become relatively technically disadvantaged.

(c) Workforce results

Table 4.6 shows the percentage shares of each occupation in the workforce in 1971/72 and in the innovative and Luddite economies of 1990/91. It also shows the growth rates in occupational employment opportunities implied by the alternative paths to 1990/91. Differences in the occupational composition of the workforces in the two 1990/91 economies and the 1971/72 economy are explained by differences in (i) the occupational compositions of their workforces within the same industries, (ii) the industrial compositions of their GDPs, and (iii) the relative productivity levels across their industries.

In the current simulations factor (i) is of little importance. We established this by checking that occupational labour demands in the IE of 1990/91 were almost unchanged when we switched to an ℓ matrix which incorporated the 1990/91 industry productivity levels but which allowed no change from the 1971/72 occupational compositions of the industrial workforces. This result is not surprising. It will be recalled from section 4.1(a) that in constructing the ℓ matrix for the IE of 1990/91 we made alterations to the 1971/72 occupational compositions in the workforces of only 12 out of the 109 industries.

The operation of the other two factors is, however, apparent in the results in Table 4.6. For example, the increase in the proportions of white collar workers (groups 1-3) and rural workers

Table 4.6 Occupational Shares in the Workforce

	I Actual 1971/72	II 1990/91 Innovative Economy[a]	III 1990/91 Luddite Economy[a]
1. Professional White Collar	3.3	3.9 (3.1)	4.0 (3.2)
2. Skilled White Collar	12.8	14.3 (2.7)	13.6 (2.5)
3. Semi and Unskilled White Collar	26.9	30.5 (2.9)	29.0 (2.6)
4. Skilled Blue Collar (Metal & Electrical)	10.9	9.0 (1.2)	9.1 (1.3)
5. Skilled Blue Collar (Building)	5.1	3.9 (0.8)	4.1 (1.0)
6. Skilled Blue Collar (Other)	2.6	2.7 (2.5)	2.7 (2.5)
7. Semi and Unskilled (Blue Collar)	32.0	30.5 (1.9)	30.6 (1.9)
8. Rural Workers	4.8	3.6 (0.5)	5.1 (2.4)
9. Armed Services	1.6	1.6 (2.2)	1.8 (2.7)
Total	100.0	100.0 (2.2)	100.0 (2.2)

(a) Figures in parentheses show annual percentage growth rates over the period 1971/72 to 1990/91. For example, professional white collar employment grows at an average annual rate of 3.1 per cent on the path to the IE.

(group 8) in the workforce of the LE compared with 1971/72 is explained by the increased share of government expenditure and agricultural output in the GDP of the LE. Similarly, the slow growth in the employment opportunities for groups 4, 5 and 7 is associated with the reduction in the shares in GDP of import competing and investment-related industries. On comparing the occupational composition of the innovative and Luddite economies of 1990/91, we see that the largest difference is the sharp decline in the share of rural workers. This result is associated with the rapid productivity improvements in the agricultural industries projected for the path to the IE (see Table 4.3, column IV). The result should not, however, be interpreted as meaning that technical progress is necessarily harmful to the employment opportunities of rural workers. In the current simulations, where exports are set independently of local cost conditions, we do not account for the likely favourable effects of technical progress on agricultural export levels and thus on rural employment.

The overwhelming impression from Table 4.6 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.

5. CONCLUDING REMARKS

In this paper we have used the SNAPSHOT model to investigate some of the implications of technical change for the Australian economy. This exercise required the assembly of exogenous projections for numerous variables describing technical, demographic and trade characteristics of Australia in 1990. In making these projections we have drawn on a variety of independent opinion. It has become apparent that SNAPSHOT has a role in checking the consistency of forecasts on technology, demography and trade from diverse sources. We can also imagine an interactive procedure whereby experts on different aspects of the economy are asked to modify their initial projections in the light of the model results.

The exogenous projections used in this paper are of the first-round type only. Furthermore, additional resources could be devoted profitably to their detailed formulation. For example, a continuation of the promising start made by the BIE in the field of forecasting production techniques would have a considerable payoff.

The paper has highlighted several limitations of programming models such as SNAPSHOT -- in particular their inability to incorporate relative prices in the explanation of international trade. In this respect, Johansen-type models, such as ORANI, are less limited. Current efforts are being made at the IMPACT Project to enhance ORANI's capabilities as a long-term model. When this work is completed, projections more convincing than those presented here (especially for industries producing traded goods) will be possible.

Subject to the qualifications expressed throughout the paper, our results indicate that rapid technical progress is particularly important for the future well-being of those Australian industries which are closely connected with international trade. At the macro level, our results support the view that technical progress is vital for securing increased GDP, increased consumption and higher real wages. Technical progress may also affect macroeconomic managment. In the absence of technical progress, we found that the "full-employment" level of real wages would decline. Under such conditions, it is difficult to imagine that Australia could achieve even a tolerable approximation to full employment.

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