IMPACT OF DEMOGRAPHIC CHANGE ON INDUSTRY STRUCTURE IN AUSTRALIA

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ECONOMY WIDE EFFECTS OF LONG RUN CHANGES IN DEMOGRAPHY, TECHNOLOGY AND INTERNATIONAL TRADE

by

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APPENDIX 1

The computing was done on the CSIRO Cyber 76 and the programs are written in FORTRAN. Use was made of three computer packages available on the CSIRO Cyber 76; Superpassion; Apex-1 and Update. Superpassion (Special Utility Program Enlarging and Revising Passion) is a matrix manipulation program while Passion is a program for algebraic sequences specifically of input-output natures. Apex-1 is a Control Data Corporation linear programming package. The Update facility provides a means of maintaining program and data checks in conveniently amendable compressed format on magnetic disc or tape.

SNAPSHOT solutions generally require from 10 to 12 iterations around figure 1. That is, the LP model is approximated and solved 10 to 12 times before all convergency criteria are satisfied. Central processing time is about 125 seconds.

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ABSTRACT

In the longer term, changes in demography, technological innovations and shifts in the patterns of Australia's international trade can be expected to significantly influence the structure of the Australian economy. A large non-linear model which simulates these long-run effects is presented and its economics discussed. The solution algorithm is solved by making piece-wise linear approximations to the non-linear objective function and the non-linear constraint functions. The linear programming problem is then solved and an approximate solution obtained. Termination tests are applied to the approximate solution. If the solution is inadequate the piece-wise approximations are revised and the linear programming solution recomputed until the termination tests are satisfied. A detailed validation exercise is then performed using historic data over the period 1962-63 to 1971-72.

5. CONCLUSION

The results demonstrate that the SNAPSHOT model is capable of projecting to a high degree of accuracy economic variables at an economy and individual industry level as well as employment by occupation. However this level of accuracy has been demonstrated only when the exogenous data inputs concerned with trade, technology and demography are known with certainty. While the test described here validates the economics of the model, further tests are required to evaluate the model's forecasting potential. For the model to be used in forecasting mode, that is, to generate solutions for a snapshot year beyond the present, the user must formulate the technology, trade and demography scenarios for the chosen snapshot year. Further testing is required to establish the relative contribution each of the components of the exogenous data base makes to the projection accuracy of the model.

Table IV contains projections of employment for each of the nine occupational groups distinguished by the model.

TABLE IV

PROJECTION OF WORKFORCE BY OCCUPATION

Occupation	SNAPSHOT Projection 000's	Actual Number 000's
1. Professional White Collar	199.4	201.9
2. Skilled White Collar	694.0	699.1
3. Semi and Unskilled White Collar	1409.2	1419.4
4. Skilled Blue Collar (metal and electrical)	536.8	532.3
5. Skilled Blue Collar (building)	223.1	219.8
6. Skilled Blue Collar (other)	139.7	140.2
7. Semi and Unskilled Blue Collar	1551.5	1545.7
8. Rural Workers	423.9	419.1
9. Armed Services	83.3	83.3

Occupational employment is also projected accurately.

CONTENTS

An important task of SNAPSHOT is to identify the longrun consequences of changes in technology, demography and trade on the performance of individual industries in the economy. The projection accuracy for key endogenous variables at an individual industry level is shown in Table III.

TABLE III

PROJECTION OF ECONOMIC VARIABLES AT AN INDUSTRY LEVEL

Variable	Projection Accuracy	
	Projected $\pm$ 5% of Actual	Projected $\pm$ 6-15% of Actual
industry output	102	7
industry consumption	88	19
industry investment	86	10
industry imports	96	9
industry growth rate	86	14

Figures in the table refer to the number of industries for which the projection of the economic variable in question lies within each accuracy range. The Australian economy is divided for the purpose of inter-industry analysis into 109 industries. The table indicates that the model is also able to project economic variables at an industry level to a high degree of accuracy.

4. ECONOMIC PERFORMANCE

SNAPSHOT's economic performance has been evaluated by assessing how accurately the model projects the endogenous variable list for the 1971/72 Australian economy from a 1962/63 starting base given the production technology, demographic and trade scenarios which actually occurred in the 1971/72 snapshot year. A comparison of projections of the key macro economic aggregates with their actual values for 1971/72 is contained in Table II.

TABLE II

PROJECTION OF KEY ECONOMIC AGGREGATES

Item	SNAPSHOT Projection ($m 1971/72)	Actual ($m 1971/72)
Consumption	20863	20724
Net taxes on consumption	1490	1492
Private investment	6388	6378
Net taxes on investment	61	79
Imports - competing	4360	4337
Imports - non-competing	658	659
Gross National Product	37095	36988
Payments to labour and capital	33848	33202
Payments to wages, salaries, supplements	20666	20176
Gross operating surplus	13182	13026
Average wage	3929	3836

The results indicate that the model projects the aggregates to a satisfactory level of accuracy.

ECONOMY WIDE EFFECTS OF LONG RUN CHANGES IN DEMOGRAPHY, TECHNOLOGY AND INTERNATIONAL TRADE *

by

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1. INTRODUCTION

We report on the economic design, solution algorithm and performance of a long term economy-wide model of the Australian economy. The model (termed SNAPSHOT) provides a detailed description of the economy for a particular year well into the future.[1] The SNAPSHOT approach allows us to analyse the effects of demographic and technological developments on industrial composition of the economy, skill composition and manpower requirements of the workforce and living standards while abstracting from short-run cyclical phenomena and the dynamics of adjustment paths.

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1. Dixon, Peter B., John D. Harrower and Alan A. Powell, "SNAPSHOT, A Long Term Economy-Wide Model of Australia : Preliminary Outline", Impact of Demographic Change on Industry Structure in Australia, Preliminary Working Paper No. SP-01 Industries Assistance Commission, Melbourne, February, 1976.

* This paper has been published by the Convening Committee of the Simulation Special Interest Group in Simulation Modelling : Techniques and Applications, Proceedings of SIMSIG - 78 : Simulation Conference (Canberra : C/- Division of Computing Research, CSIRO, 1978), pp. 109-113.

2. MODEL SPECIFICATION

Table 1 lists the SNAPSHOT equations. A brief description of the underlying economics is as follows:

2.1 Consumption

Households are divided into nine groups chosen to reflect different consumption patterns on the basis of socio-economic characteristics such as age of household head and number of children. Consumption preferences of groups are represented by different utility functions of the Klein-Rubin functional form, with demand behaviour obtained by maximising the utility functions subject to group budget constraints. The real after-tax proportional distribution of disposable income across demographic groups in the snapshot year is set exogenously.

2.2 Capital Stocks, Investment and Rates of Return

Capital stocks in the snapshot year are obtained by multiplying base year stocks (exogenous) in each industry by an endogenously determined average growth factor over the snapshot period. Investment by each industry in the snapshot year is assumed to be sufficient to maintain the snapshot period growth rates. Relative rates of return on capital to induce investment in each industry are set exogenously. The relativities account for such factors as risk and industry concentration. This formulation does allow industries to be affected by changes in productivity caused by demographic and technological change, by changes in world prices or by changes in

(j) Calculate final solution variables. When an acceptable solution is finally found, various extra quantities based on the solution values are calculated and printed out.

Each of the above steps was chosen to be a single problem step. For model and program debugging, an extra printing step was added after each of the calculation steps. All of the steps were then coded as separate subroutines, and a main program was written to control the step execution of the problem. A simple set of commands was defined to represent each of the steps, and a main program was written to read in the commands one by one and execute them. This command structure gave the flexibility during debugging to execute as little or as much as was required without disturbance to the program code.

The computing strategy incorporated ideas from modular programming. Use of these ideas simplified the program coding and debugging. The main program does no mathematical work whatsoever. Its only task is to read a command, decide which command it is, and to call the appropriate subroutine to do the mathematics for that step. Each of the individual "worker" subroutines was deliberately coded to handle the mathematics for only one simple step of the algorithm. In this way, its function was clear and it could be easily identified if an error occurred. If a single step was complicated, some of the subtasks were coded into "helper" subroutines which were then called by the "worker" when needed. Thus the trap of writing large, hard to understand sections of code was avoided. Details of the simulation facilities are contained in Appendix 1.

(b) Initialise iterative variables - make predictions of the values that some simple variables will take in the final solution.

(c) Calculate re-estimated variables - based on the prediction in (b), linear approximations to the non-linear parts of the model are made.

(d) Generate the LP model using data from (a), (b) and (c) to calculate the LP coefficients.

(e) Solve the LP - an LP package external to the solution controlling program is used.

(f) Read LP solution - extract from the LP solution, primal (activity levels) and dual solutions values.

(g) Calculate post-LP variables - other economic variables are now calculated from LP solution values.

(h) Test for final solution - various tests are made on the iterative variables, LP variables and post LP variables to determine whether or not the solution has converged to sufficient accuracy.

(i) Adjust iterative variables. If the errors in the LP approximation are too great, the assumptions are refined in preparation for a re-run starting at step (c). The adjustment rules determine the speed of convergence. Ideally the adjustments are dynamically controlled so that smaller variations are made as the model gets closer to the optimal solution.

protection policy. The effects of these changes, however, are on the size (capital, output, employment) of the industry and not its rate of return to capital.

2.3 International Trade and Commodity Prices

It is well known that general equilibrium models that combine the assumption of linear production technology with perfect substitution between imported and domestic products and exogenous prices for exports and imports produce solutions in which domestic production is specialised to an unrealistic extent. We obviate this problem in SNAPSHOT by making international trade largely exogenous. Exports are specified exogenously on the basis of long term projections, while the maximum shares of domestic markets captured by imports are also set exogenously.

To enable the export target levels to be achieved and to ensure that import penetration does not exceed the set levels, it is necessary to introduce a series of taxes and subsidies which allow the domestic price pattern to deviate from the exogenous pattern of world prices projected for the snapshot year. In particular, discriminatory tariffs to restrict imports to domestic market shares may be needed and are determined endogenously. Similarly, in the light of the endogenous domestic cost structure in the snapshot year, the local levels of demand for and outputs of exportables may not be consistent with the set export targets. Consistency is achieved by the endogenous imposition of an appropriate export tax or subsidy.

2.4 Balance of Trade and Exchange Rate

The balance of trade is set exogenously according to an assessment of the net inflow or outflow of capital likely to occur. The exchange rate, which is endogenous, adjusts to ensure that the SNAPSHOT solution is consistent with this assessment about international capital movements.

2.5 Cost Structure of Commodities

The cost of producing a commodity is made up of purchased materials, wages and salaries, the return on capital and taxes levied on inputs. Should the cost of production of a commodity exceed its price, then that commodity is not produced in the snapshot year.

2.6 Clearing of Commodity Markets

SNAPSHOT is a general equilibrium model which matches the demand and supplies. For each commodity, the sum of domestic production and the net balance of imports over exports must equal the demands generated by consumers plus investors plus government.

2.7 Labour Market and Wages

The size of the workforce in the snapshot year is specified exogenously. The distribution of employment over nine occupational groups is endogenous and demand determined. That is, SNAPSHOT indicates which occupational composition of the labour force would be consistent with the projected structure of the economy in the snapshot year, given an exogenously set total workforce.

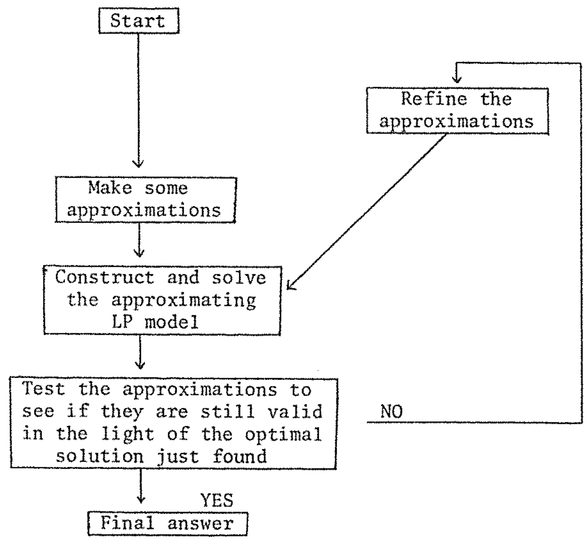

Figure 1

The main computing task was to develop a system which makes it easy to; (i) transfer input data required for the basic program (LP) to the LP package (APEX-1), (ii) solve the LP, and (iii) transfer the LP solution back from the LP package. With the whole process of approximating and refining the approximations under computer control, accurate solutions can be quickly obtained.

The complete SNAPSHOT solution algorithm may be described as follows:

(a) Read fixed data - read and store variables and matrices of data external to the model such as observed data and exogenous variables.

a weighted additive non-linear utility function where the weights are arrived at iteratively to ensure the appropriate distribution of total consumer expenditure across the consumer groups.[1]

For example, the objective function is initially written in terms of maximizing $\sum_i w_i U_i(C_i)$, a weighted sum over the utility functions of the 9 groups of consumers. This may be reformed as maximise $U(w^+,C)$ where $U(w^+,C)$ is the maximum value attainable for $\sum_i w_i U_i(C_i)$ where the C_i are an allocation of the aggregate vector C across consumers and w^+ is the vector of weights $(w_1^+,\ldots,w_m^+)$. This step reduces the number of variables in the non-linear objective function from nm to n. Furthermore Dixon[1] has shown that if the U_i are strictly concave additive functions then $U(w^+,C) = \sum_j V_j(w^+,C_{\cdot j})$ where $C_{\cdot j}$ is the j^{th} element of C and $V_j(j=1,\ldots,n)$ are strictly concave additive functions (with respect to $C_{\cdot j}$). We now have a standard non-linear additive objective function. This may be linearised by conventional methods which in this case involves approximating the V_j by t linear segments over the likely solution range of $C_{\cdot j}$.

Since the number of non-linear coefficients in the objective function and constraints is small in relation to the total number, the problem can be further approximated by an appropriately constructed linear model. The basic solution strategy (figure 1) is to make piece-wise linear approximations to the non-linearities, solve the LP problem and check to see whether the linear approximations are still valid in the optimal solution. Termination tests are applied to the approximate solution and if the solution is inadequate the approximations are revised and the LP solution recomputed.

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1. Dixon, Peter B., "A joint Algorithm for the solution of SNAPSHOT", Impact of Demographic Change on Industry Structure in Australia, Preliminary Working Paper No. SP-03, Industries Assistance Commission, Melbourne, April, 1976.

The relative wages of the different occupations are exogenous. The absolute wage however, is endogenous, its level being determined by the productivity of the economy in the snapshot year and the requirement that the specified workforce be employed. Implicit is the assumption that between the base period and the snapshot year, occupational mobility, training and retraining, and the response of the education system are adequate to ensure that the supplies of different skills in the snapshot year match the demands for them.

2.8 Gross National Product

This represents the sum of wages, rents on capital, taxation levies and tariff revenue less export subsidies.

TABLE 1

THE EQUATIONS SPECIFYING THE SNAPSHOT MODEL

Equation Equivalents	Equation	
mg	$C_i = f_i(p^c, Z_i), \quad i=1,\ldots,m$	(1)
g	$p^c = Q'p + Q'\hat{t}_c\, p$	(2)
m	$Z_i = (1 - s_i)\, \alpha_i(GNP)$	(3)
n	$K(t) = (I + \hat{h})^t\, \overline{(K(0))}$	(4)
n	$K(t+1) = (I + \hat{h})(K(t))$	(5)

Equation Equivalents	Equation	
n	$J = K(t+1) - (I - \hat{\eta})(K(t))$	(6)
n	$X \leqslant K(t)$	(7a)
	$\Pi\ (X - K(t)) = 0$	(7b)
n	$r = \beta\bar{r}$	(8)
n	$r \geqslant (\widehat{p^K})^{-1}\ \Pi - \eta$	(9a)
	$\hat{J}(r - (\widehat{p^K})^{-1}\ \Pi + \eta) = 0$	(9b)
n	$p^K = K'p + (T_2 * K)'p$	(9c)
n	$E = \bar{E}$	(10)
n-1	$M \leqslant \hat{\gamma}X$	(11a)
	$\hat{\phi}\ (M - \hat{\gamma}X) = 0$	(11b)
n	$p = \Theta\overline{p^e} + \xi - \hat{t}_E p$	(12)

Number of Variables

(In addition to the above list of exogenous variables, U_i, the utility function of the i^{th} consumer group, is specified as $U_i = \sum_j \beta_{ij}\ \ell n\ (C_{ij} - \gamma_{ij})$ where β_{ij} is the marginal budget share of group i's expenditure on good j, and γ_{ij} is the subsistence expenditure of group i on good j.)

Q	transformation matrix between the number of consumer goods and the number of input-output industries	(nxg)

The letters n, g, m and H represent the dimensions of variables and data in the problem as follows:

$n = 110$, the number of industry groups (including non-competing imports)

$g = 9$, the number of consumer goods

$m = 9$, the number of consumer groups

$H = 9$, the number of occupational groups.

3. SOLUTION TECHNIQUE

Inspection of Table 1 reveals a large non-linear system of equations and inequalities. To obtain values for the endogenous variables, the problem can be formulated in terms of maximising the utilities of the nine consumer groups subject to a set of linear and non-linear constraints. Using the theory of joint maximization (to transform the problem of many economic units into a single unit) the problem can be restated in terms of the constrained maximization of

		Number of Variables
$\overline{K(0)}$	industry levels of capital stock in the base year	(n)
t	number of years of the snapshot period	(1)
η	industry specific depreciation rates applicable to the industry capital stocks, K(t), over the t^{th} year	(n)
K	capital matrix in the snapshot year: K_{ij} is the input of good i required to create a unit of capital stock for industry j	(nxn)
T_2	ad valorem taxes on creation of capital stock	(nxn)
$\bar{r}$	relative rates of return to capital required to induce investment in each industry	(n)
$\bar{E}$	exports of commodities	(n)
t_E	ad valorem taxes (net of subsidies) on exports	(n)
γ	import shares of the domestic markets	(n)
$\overline{p^e}$	export prices (f.o.b.) in foreign currency	(n)
$\overline{p^m}$	import prices (c.i.f.) in foreign currency	(n)
$\bar{\tau}$	ad valorem tariff rates	(n)
$\bar{B}$	balance of trade deficit in foreign currency	(1)
A	input-output coefficients matrix	(nxn)
T_1	ad valorem taxes on intermediate usage	(nxn)
ℓ	labour requirements by occupation and industry per unit of output in the snapshot year	(Hxn)
$\bar{G}$	government purchases of commodities	(n)
$\bar{N}$	total number of people in the workforce in the snapshot year	(1)
$\bar{w}$	relative wage rates, before taxes, for the various occupational groups	(H)

Equation Equivalents	Equation	
	$p' \leq \Theta(\overline{p^m})'(I + \hat{\bar{\tau}}) + \phi'$	(13a)
n		
	$[p' - \Theta(\overline{p^m})'(I + \hat{\bar{\tau}}) - \phi']\hat{M} = 0$	(13b)
	$B \geq (\overline{p^m})'M - (\overline{p^e})'E$	(14a)
1		
	$\Theta(\bar{B} - (\overline{p^m})'M - (\overline{p^e})'E) = 0$	(14b)
	$p'(I - A) - w'\ell - \Pi' - p'(T_1 * A) \leq 0$	(15a)
n		
	$[p'(I - A) - w'\ell - \Pi' - p'(T_1 * A)]\hat{X} = 0$	(15b)
	$X + M \geq Q\sum_{i=1}^{m} C_i + KJ + \bar{G} + E + AX$	(16a)
n		
	$\hat{p}\,[X + M - Q\sum_{i=1}^{m} C_i - KJ - G - E - AX] = 0$	(16b)
	$\bar{N} \geq 1'L$	(17a)
1		
	$\delta(\bar{N} - 1'L) = 0$	(17b)
H	$L = \ell X$	(18)
H	$w = \delta(\bar{w})$	(19)

Equation Equivalents	Equation	
1	$GNP = w'L + \Pi'K(t) + [\Theta(\overline{p^m})'\hat{\bar{\tau}}$	(20)
	$+ \phi']M - \xi'E + p'[Q\hat{t}_c \sum_i C_i$	
	$+ (T_2 * K)J + \hat{t}_E\bar{E} + (T_1 * A)X]$	
	All endogenous variables (with the possible exception of h and ξ) must by non-negative.	(21)

ENDOGENEOUS VARIABLES IN THE SNAPSHOT YEAR

		Number of Variables
C_i	consumption of commodities by consumer group i	(gm)
p	commodity prices	(n)
p^c	consumer prices including taxes	(g)
Z_i	total expenditure of consumer group i	(m)
GNP	gross national product	(1)
h	average rate of growth of capital in each industry over the t-year snapshot period	(n)
K(t)	industry levels of capital stock in the snapshot year	(n)

		Number of Variables
K(t+1)	industry levels of capital stock in the year after the snapshot year	(n)
J	gross investments by using industries	(n)
X	outputs of commodities	(n)
Π	rental prices on capital by industries	(n)
p^K	price of capital goods including taxes	(n)
r	minimum acceptable rates of return by industry	(n)
β	variable reflecting the absolute rate of return demanded on new capital formation in Australian industries	(1)
E	exports of commodities (quantity)	(n)
M	imports of commodities (quantity)	(n)
Θ	exchange rate ($A per unit of foreign currency)	(1)
ϕ	excess tariff revenue per unit of imports	(n-1)
ξ	export subsidy	(n)
w	wage rates by occupation before taxes	(H)
L	the number of labour units in each occupational group in the snapshot year	(H)
δ	variable reflecting the absolute level of wages before taxes for the Australian labour force	(1)

EXOGENEOUS VARIABLE IN THE SNAPSHOT YEAR

s_i	consumer group i's average propensity to save out of disposable income	(m)
α_i	share of GNP which is disposable income for group i	(m)
t_c	ad valorem taxes on consumption	(n)