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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

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ASPECTS OF THE DESIGN OF *BACHUROO*, AN ECONOMIC-DEMOGRAPHIC MODEL OF LABOUR SUPPLY

by

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

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Aspects of the Design of BACHUROO, An Economic-Demographic Model of Labour Supply

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1. Introduction : The IMPACT Framework

BACHUROO is one of four models under development by members of the IMPACT Project team. The Project itself, now some five years old, is an inter-agency initiative of the Australian federal government in co-operation with the University of Melbourne. Its aim is to facilitate the analysis of the impact of economic, demographic, and social changes on the structure of the Australian economy. Here 'structure' refers particularly to the industrial composition of GDP, the occupational composition of employment, and patterns of international trade. The Project has concentrated on data mobilization, model building, human capital formation in the areas of model building, manipulative, and interpretive skills, and on associated computer systems.[1]

Besides BACHUROO, the models of the IMPACT Project are called ORANI (a large computable general equilibrium model in the Johansen (1960) family), MACRO (a small continuous-time disequilibrium model in the

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* I am grateful for helpful comments and suggestions to my colleagues, Dennis Sams, Ashok Tulpulé and Lynne Williams. All errors are my own.

1. Further institutional and historical details may be found in Rattigan (1976), Powell ((1977), pp. 4-14)), Powell and Parmenter (1979), and Dixon, Powell and Parmenter ((1979, pp. ix-xi).

Bergstrom-Wymer (1976) - Jonson (1976) family), and SNAPSHOT (a non-linear programming model in the Sandee (1960) - Bruno (1966) - Manne (1963) - Evans (1972) family). The last of these is designed to be used almost exclusively in stand-alone mode and need not concern us further. It is necessary, however, to understand BACHUROO's relationship to MACRO and ORANI if one is to obtain a clear idea of the role of BACHUROO. These three models, when linked, will constitute IMPACT's medium term model.

ORANI is a very large model which can be used to disaggregate an exogenously given set of macro aggregates into activity levels for about 100 input-output industries. In so doing, ORANI endogenizes demands for labour disaggregated by the 9 occupational groups shown in Table 1. As

Table 1 : Major Occupation Groups Used in IMPACT

1.	Professional White Collar
2.	Skilled White Collar
3.	Semi and Unskilled White Collar
4.	Skilled Blue Collar (Metal and Electrical)
5.	Skilled Blue Collar (Building)
6.	Skilled Blue Collar (Other)
7.	Semi and Unskilled Blue Collar
8.	Rural Workers
*9.	Armed Services

* Armed Services are included for completeness of coverage. They are usually excluded from labour force statistical collections and are modelled largely exogenously in IMPACT, although they impinge indirectly by employing persons who would otherwise be available for the civilian labour force. A separate group 'Lecturers and Teachers' is sometimes extracted from groups 1 and 2, as in Williams (1980) and Tulpulé (1980 a).

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well, relative prices, profitability, imports, exports and a large number of other variables are endogenized by ORANI. MACRO's role is to provide macroeconomic closure for ORANI in short and medium term applications,[1] while the role of BACHUROO is to provide closure with respect to the labour market. ORANI endogenizes, at a given set of wage rates, the demand for labour in different occupations; it is BACHUROO's task to endogenize the corresponding supplies. A schematic diagram of the planned linkages between the three models for short and medium term applications is shown in Figure 1.

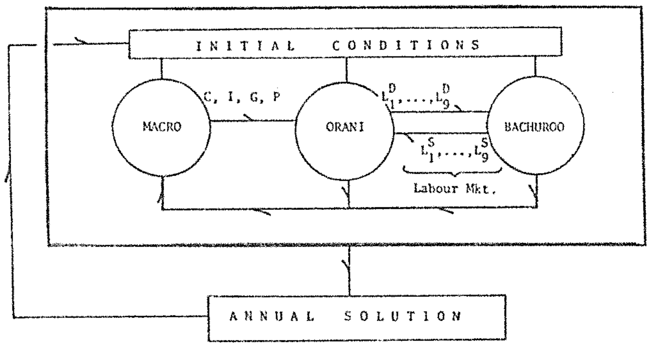

Figure 1

SIMPLIFIED DIAGRAM OF MEDIUM TERM MODEL. The levels of consumption C, real investment I, real government spending G, and the general price level P, may be thought of as originating in MACRO. ORANI disaggregates these into 113 input-output industries and determines relative prices of commodities, imports and exports by I-O industry, and (if wage rates are given), labour demands by nine occupations. BACHUROO determines the supplies of labour by occupation. Excess demand for or supply of labour can feed back into the macroeconomic environment. Interactively the three models will, given a set of initial conditions, produce an annual solution which then determines a new set of initial conditions for a second annual solution; and so on.

(After Powell and Parmenter (1979)).

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1. Short and medium term applications are those whose focus does not extend beyond (say) three years. ORANI may also be used for long term projections - - see Vincent (1980). BACHUROO will also be suitable for long term projections.

The current (November 1980) state of development of the IMPACT models is as follows. SNAPSHOT is fully developed and has been validated (Dixon, Harrower and Vincent (1978)) and used to investigate structural aspects of currently foreseen technical changes in production techniques (Dixon and Vincent (1980)). ORANI has gone through two complete development cycles (Dixon, Parmenter, Ryland and Sutton (1977); Dixon, Parmenter, Sutton and Vincent (forthcoming)); only a comparatively minor set of additional enhancements in model design are currently contemplated. Some 18 applications papers using the ORANI model have been written by members of the IMPACT team, and several others by other researchers.[1] MACRO has been developed by a separate, independent team at the Reserve Bank of Australia; it has been through two cycles of development (Jonson, Moses and Wymer (1978); Jonson and Trevor (1979); Jonson, McKibbin and Trevor (1980)) and adapted for use by IMPACT (Cooper and McLaren (1980)). The methodology for interfacing a Johansen model (like ORANI) with a Bergstrom/Wymer model (like MACRO) has been developed, and experimental interfacing of these two models is well under way (Cooper and McLaren (1980)). BACHUROO, the topic of the remainder of this paper, is only partially developed. A major limitation has been the failure of the Project's sponsor to commit sufficient high level professional resources to this model.[2] Other factors accounting for the delay include the prevalent slack labour market, which has made

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1. For a catalogue of publicly available documentation, write to the IMPACT Information Officer, Mr. M. Kenderes, Industries Assistance Commission, P.O. Box 80, Belconnen, 2616. ACT, Australia. In terms of the catalogue nomenclature, the following papers report ORANI applications : R-01, R-02, R-03, OP-19, OP-25, OP-26, IP-04, G-03, G-04, G-06, G-17, G-18, G-22, G-23, G-25, G-26, G-27, G-28.

2. The urgent need to do so had been pointed out publicly by the Project's director as early as 1977 - - see Powell (1977), p. 173.

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but not at another (Caddy, Jackson and Powell (1978)). The internal politics of immigration and the external supply conditions for immigrants have changed so radically since the late sixties as to make it very unlikely that an econometric approach would successfully endogenize the interaction of government policy and overseas conditions. Accordingly, immigration is to be handled as a set of exogenous variables for which, like education, specific purpose scenarios must be written by the model user.

While its scope has narrowed to this extent, in other ways the model has become much more ambitious. Given its intended policy-analytic role, it is most important that linkages between economic and demographic variables be captured in a way which will allow counterfactual simulation. The micro-underpinnings of the model have accordingly been considerably strengthened.

My final perspective concerns the conservative strategy which we have adopted towards interfacing the various components of BACHUROO. This is a microcosm of the strategy adopted towards the interfacing of ORANI with MACRO. If one is to have any idea, in the context of such large models, about the features of the model which are responsible for producing particular simulation results, it is necessary first to understand very well each of its components, and to have developed an appropriate methodology for interfacing them. IMPACT will not, for instance, attempt to make illustrative projections with BACHUROO as a whole in stand-alone mode until satisfactory, well understood, projections have been made with each of its components. This may seem to slow down the rate of progress, but that is an illusion. Unsatisfactory simulations produced with a whole whose parts are individually of doubtful status would leave the user forever in a quandary as to what went wrong.

supply side constraints less urgent in the perception of policy makers, and the abysmal state of the available Australian labour market data base (Mumme et al. (1978)).

With this much as background, the aim of the present paper is to review the design of IMPACT's demographic and labour supply model, BACHUROO, and to report on progress in its construction. Aspects emphasized in this account are those which we believe to be of potential methodological interest to other modellers.

2. The Structure of BACHUROO

The approach we have followed can be discussed conveniently in terms of attempts to answer the following hypothetical questions : for a given projection date, and given a particular scenario on a host of relevant economic variables (many of whose values are endogenized by ORANI-MACRO),

(i) How many people of potentially working age would there be in the population?

(ii) How many of these people would, given the postulated conditions, choose to work?

(iii) What would the occupational composition of this hypothetical workforce be?

(iv) For those who would choose to work, what number of hours of work per week would they offer under the postulated conditions?

Because of the strong links between fertility and labour force participation by females, (i) and (ii) are best handled simultaneously. The modules of BACHUROO dealing with demographic accounting and with family formation, female workforce participation, and fertility, are referred to jointly as the demographic core of the model (Sams (1979)). Closely allied is the question of household formation, which is treated below under the same heading. To question (iii) we have adopted a new approach based on the concept of an occupational transformation frontier (Parham and Ryland (1978), Craigie, Parham and Ryland (1979), Williams (1980)). This allows, within the limits set by the existing composition of the skills of the workforce, a flexible response in its occupational composition to changing occupational wage relativities and relative risks of unemployment. In coming to terms with question (iv) the standard neoclassical model of labour-leisure choice has been extended to include demographic linkages and an endogenous marginal wage rate (Powell, Tulpulé and Filmer (1977), Powell (1980b)). Our approaches to (iii) and (iv) are dealt with below under the headings occupational disaggregation and labour-leisure choice respectively.

2.1 The Demographic Core[1]

The major roles of the demographic core are to provide projections of the population by sex, marital status and single years of age, of the size of the labour force by sex, marital status and three age groups, and the number of households by sex, marital status and quinquennial age group of the head. We have employed conventional demographic accounting

1. This section draws heavily on Sams (1979) and on Sams and Williams (1980).

ΔM^u, ΔH^u) is set exogenously to the particular value (0, 0, 0), the medium term model will yield the shadow wage rates and other conditions of employment which would, in a certain sense, clear the labour market.[1]

The alternative methods of closure described above are adequate for policy analysis, which is the principal focus of the IMPACT Project. Clearly, for forecasting, they are not. My own view is that at the present time the state of the art does not allow forecasters of the Australian economy to predict, with any confidence, which particular bargains in terms of real wages and unemployment will be struck. To forecast with the medium term model, therefore, scenario-writing with a substantial element of political and industrial relations know-how will be needed.

4. Concluding Remarks

Those who are familiar with the early documents on the design of BACHUROO (Tulpulé and McIntosh (1976); Tulpulé (1976); Powell (1977), Section 3.3) will have noted that the scope and design of the endeavour have undergone substantial evolution. Some areas in which it was initially hoped that the behaviour of the relevant agents could be endogenized proved, for one reason or another, too hard. The main examples are (a) the education sector, (b) immigration flows, and (c) mapping from the functional to the personal distribution of income. In the case of (a) and (c) the limited Australian data bases will preclude serious work for the foreseeable future. In the case of immigration, it was possible to endogenize government policy during the postwar period at one level of sophisitication (Kelley and Schmidt (1978))

1. If the initial conditions from which the solution is computed involve labour market equilibrium in the sense that $(L^S, M^S, H^S) = (L^d, M^d, H^d)$, then setting $(\Delta L^u, \Delta M^u, \Delta H^u)$ to zero results in the labour market clearing absolutely. If some other initial set of conditions is used, setting the last mentioned vectors to zero results in a projection involving no change in the degree of disequilibrium in the labour market.

(ℓ^S, m^S, h^S) for given employment conditions $(\Theta_o, \Theta_1, \Theta_2)$; or alternatively, will endogenize the employment conditions which would be consistent with a given scenario on labour supplies.

To discuss the interface of ORANI-MACRO with BACHUROO, we need some further notation :

(25.1) $$\Delta L^u \equiv \ell^S L^S - \ell^d L^d ,$$

(25.2) $$\Delta M^u \equiv m^S M^S - m^d M^d ,$$

(25.3) $$\Delta H^u \equiv h^S H^S - h^d H^d .$$

These variables are to be interpreted as follows. Upper case letter represent the levels of the corresponding lower case variables. Thus M^S is the number of man-hours supplied, while m^S is the proportional change in this variable. If positive, ΔL^u is the increase in the number of unemployed people; if negative, it represents the increase in unfilled vacancies. If positive, ΔH^u is to be interpreted as an increase in underutilization of those people who are in employment; if negative, as an increase in unfilled demand by employers for additional overtime hours. Finally, ΔM^u, if positive, indicates an increase in overall slackness in the labour market; if negative, an increase in overall excess demand.

The complete IMPACT medium term model, in proportional change form, will be obtained by adding BACHUROO's structural form equations, plus the equation set (25.1) to (25.3) to ORANI-MACRO. The same type of condensation of the notation as was discussed above for the ORANI-MACRO interface would again be carried out, and the solution procedure would follow the ORANI strategy.

What will the total system ORANI-MACRO-BACHUROO endogenize? At given conditions of employment $(\Theta_o, \Theta_1, \Theta_2)$, the vectors of changes in excess labour supplies $(\Delta L^u, \Delta M^u, \Delta H^u)$ will be obtainable from its solution. Alternatively, if the latter are set exogenously, the corresponding conditions of employment (if they exist) will be endogenized. If the vector $(\Delta L^u$,

techniques for the purpose of projecting the population but have extended them to allow their integration with an econometric model which endogenizes changes in the behavioural characteristics of the population in response to changes in the social and economic environment.

The linkage between the econometric model and the demographic accounting equations is through such variables as propensities to marry, divorce and remarry, the means and variances across ages at given points of time of the age-specific rates of marriage, divorce and remarriage, the mean and variance at given points of time of desired family size, and the number of first nuptial confinements. These time-dependent parameters are used to summarize various age distributions which appear in the demographic accounts. They appear, in the econometric model, as endogenous behavioural variables. The econometric model relates them to each other, to other endogenous variables (such as child quality and female labour force participation rates), and to a set of exogenous economic and social variables (such as the female/male wage relativity, and infant mortality) (Filmer and Silberberg (1977)).

The econometric model is based on the 'new home economics'[1] thus providing a consistent framework of family decision making within which family formation, fertility and labour force participation by women are inter-related. Within this framework, fertility is treated as a sequential decision making process in which we attempt to capture the succession of marriage, first confinement and the progression to further children. The central construct in this decision process is the implicit desired ultimate family size which is related to the 'child quality' concept of the 'new home economics' and to the social and economic environment (Filmer and Silberberg (1977), Sams (1979), and Sams and Williams (1980)). The relationship of

1. For a collection of papers defining the scope of the 'new home economics,' see T. W. Schultz (ed.) (1973).

this econometric model to the rest of the demographic core is shown in Figure 2.

Within the demographic accounting framework we explicitly deal with 101 single years of age for four marital states : never married, married, divorced and widowed; and with five types of marital status change for each age : marriages of never married, divorced and widowed persons, plus divorces and widowings. We do not attempt to build 101 separate age-specific equations for each of these changes. In general, we fit a 3 parameter gamma distribution[1] across ages in each year of the sample period (1921-76) (Williams (1979)). This generates a times-series of parameters with the following interpretation :

(a) an index of propensity (to first marry, to remarry, or to divorce); that is, the area under the frequency distribution of age-specific rates (of first marriage, remarriage or divorce) ;

(b) the mean of the age distribution of age-specific rates (of first marriage, etc.) ;

(c) the variance of the age distribution of the age-specific rates.

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1. For example, for divorces, we approximate the divorce rate $d(x)$ at age x $(x > x_o)$ as

(1) $$d(x) = \frac{P}{\alpha^{\beta}\,\Gamma(\alpha)} (x - x_o)^{\alpha-1} e^{-(x-x_o)/\beta} ,$$

where P is the index of the propensity to divorce, $M \equiv \alpha\beta + x_o$ is the mean of the age distribution of the age-specific divorce rate, and $V \equiv \alpha\beta^2$ is the variance of the age distribution of the age-specific divorce rate. On occasion, it has been necessary to go as far as five parameters (of which three are time dependent and two stationary) in order to capture distributions accurately. See Williams (1979), Appendix 1.

Where does BACHUROO fit into all this? First, it should be noted that (like ORANI) its initial building blocks are not equations which are linear in log differentials. Its functions are, however, analytic and so a local representation of the model which is locally linear in proportional changes can be presumed to exist. At this stage it is not clear whether the optimal approach to obtaining such a linearization of BACHUROO would involve numerical or algebraic differentiation. If the latter, a computer implementable analytic differentiator will be needed, since BACHUROO's structure is not nearly so amenable to algebraic manipulation as ORANI's or MACRO's. In any event, let the linear-in-proportional-changes representation of BACHUROO's structural form be

(21) $$B_B\, y_B + C_B\, z_B = 0 .$$

This set of equations will be derived from the modules of BACHUROO described above. Among them will be equations for the supplies, by occupations, of men, and of man/hours per man. Let these equations be

(22) $$\mu(\ell^S, \Theta_o, \Theta_1, \Theta_2, X) = 0 ,$$

and

(23) $$\xi(h^S, \Theta_o, \Theta_1, \Theta_2, X) = 0$$

respectively, where X is a subset of $\{y_B , z_B\}$. Parallel to (19) we have the identity

(24) $$m^S \equiv \ell^S + h^S ,$$

where m^S is the vector of man-hours supplied by different occupations. Then, in stand-alone mode, BACHUROO will endogenize labour supplies

(17) $$\phi(m^d, r, x) = 0 ,$$

where x is a subset of the other variables in the combined system. It is intended to respecify this equation so that Θ_o , Θ_1 and Θ_2 appear explicitly :

(18) $$\phi^*(m^d, \Theta_o, \Theta_1, \Theta_2, x) = 0 .$$

As a matter of identity, the proportional changes h^d in the number of hours per week on average demanded per man and ℓ^d in the number of men demanded are related to m^d by the vector equation

(19) $$m^d \equiv h^d + \ell^d .$$

Missing in ORANI-MACRO at this stage, but to be added before interfacing with BACHUROO, is an equation to endogenize the proportions in which m^d splits in equation (19); let this missing structural form equation be

(20) $$\nu(\ell^d, \Theta_o, \Theta_1, \Theta_2, x) = 0 .$$

Then, given the existing flexible facility for choosing which variables shall be endogenous and which shall be exogenous that characterizes the ORANI computing system, the ORANI-MACRO system in any simulation could be used either :

(a) to endogenize the occupational demands for men (ℓ^d), for hours per man (h^d) and for man-hours (m^d) at a given set of employment conditions (Θ_o, Θ_1, Θ_2) ;

or

(b) to endogenize the employment conditions (Θ_o, Θ_1, Θ_2) which would be compatible with a given set of occupational demands (ℓ^d, m^d, h^d) .

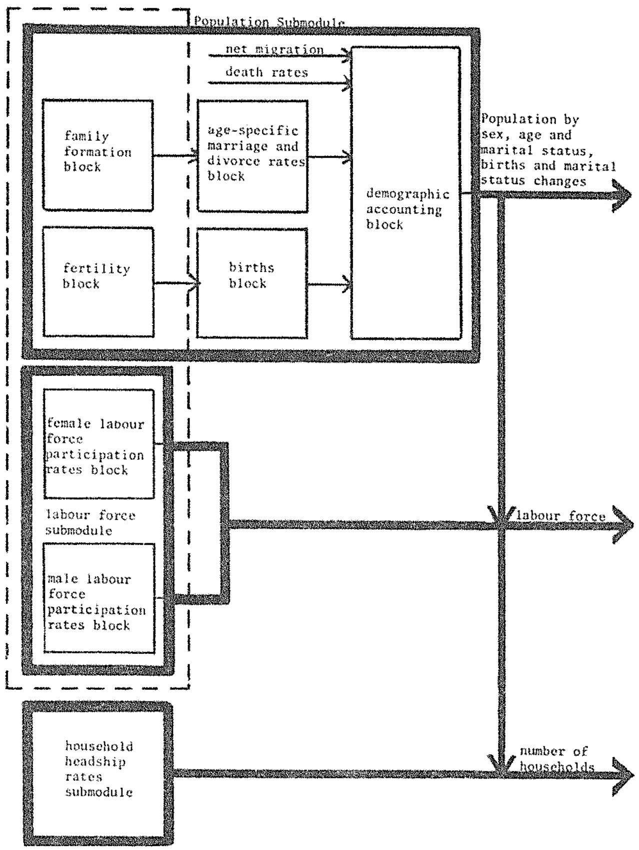

Figure 2: Schematic diagram of the demographic core of BACHUROO. The econometric model of family formation, fertility and labour force participation is contained within the dashed lines. (After Sams (1975).)

Three typical approximations are illustrated in Figure 3, and the time-series for the parameters are illustrated in Figure 4. The condensation of the age distributions of the behavioural characteristics in this way provides a manageable number of endogenous variables for the econometric model. Working in the reverse direction, the values of the parameters supplied as projected endogenous variables by the econometric model can be used to construct the age distributions of the relevant variables. Thus the entire age distribution of the behavioural variables of interest can be projected in response to changes in exogenous variables. Given the highly disaggregated level at which we seek to track the population over time, this is an essential step in interfacing the demographic accounting framework with the econometric model.

The econometric model introduces certain relationships between the demographic variables but further strong relationships are also imposed by careful attention to the preservation of necessary stock-flow identities within the accounting framework. For example, widowings are endogenized by the deaths of married men. As in conventional demographic modelling, the previous history of the population (as reflected in its age structure) exerts a strong influence on the evolution of the demographic variables through simulated time. Thus, to quote Sams (1979, p. 37)

> "[Our approach to] the modelling of age-specific rates of marriage and divorce enables the [demographic core] to separate the effects of changes in behaviour from changes in the demographic structure of the population due to the mere effluxion of time (i.e., ageing). This simplifies the task of the econometric model by limiting its role to capturing the behavioural changes and not those arising from mechanical changes in the population

algebraic substitutions which take into account the overlapping variables, the combined system can be written

(15) $$B_S\, y_S + C_S\, z_S = 0 ,$$

whose solution is

(16) $$y_S = - B_S^{-1}\, C_S\, z_S .$$

The computational approach to the solution of ORANI is amenable to the addition of extra variables and equations. Thus the macroeconomic closure of ORANI can be thought of as the addition to ORANI of extra variables and extra equations prior to solution. Elsewhere (Powell (1980a)) I have argued that in view of new developments (Dixon, Parmenter, Sutton and Vincent (forthcoming), Ch. 5) which allow the elimination of linearization errors from Johansen models at low cost, the flexibility, ease of computation and transparency of the latter class is likely, in time, to lead to its acceptance as the dominant method for the formulation and solution of non-linear economy-wide models.

The demand for labour by occupational group is endogenized in ORANI. At present the relevant variable is the vector m^d of (percentage changes in) man-hours of labour demand for the various occupations. Following the notation of Section 2.3, let the vectors of occupational-specific basic hourly wage rates, of standard hours, and of overtime progression parameters be θ_o , θ_2 and θ_1 respectively. Currently, only a vector r of overall average wage rates for each occupation is recognized in ORANI. Thus the existing ORANI-MACRO structural form equation for m^d is of the form

(12) $$y_M = A_M z_M ,$$

where y_M and z_M respectively are the endogenous and exogenous MACRO variables.

Prior to the final forms (11) and (12), the structural forms of the model appear as

(13a) $$B_o y_o + C_o z_o = 0 ,$$

and

(13b) $$B_M y_M + C_M z_M = 0 ,$$

so that the essence of the solution procedures for the models in stand-alone mode is the computation of

(14a) $$A_o = - B_o^{-1} C_o ,$$

and

(14b) $$A_M = - B_M^{-1} C_M$$

respectively. What makes (13a) and (13b) a system (as distinct from two independent systems) is the fact that some of the ORANI exogenous variables are endogenized in MACRO, so that certain elements of y_M and z_o overlap (for instance, the growth rate of aggregate consumption expenditure). The second connection, less important for viewing ORANI-MACRO as a system, is that they share some common exogenous variables (z_o and z_M overlap). Note, however, that y_o and y_M must be disjunct.[1] After appropriate

1. At the date of writing there remain less than half a dozen scalar variables which are doubly endogenized. The double endogeneities provide an indirect check on the simulation properties of ORANI via MACRO -- see Powell (1980 a). At the final interface these double endogeneities will be eliminated.

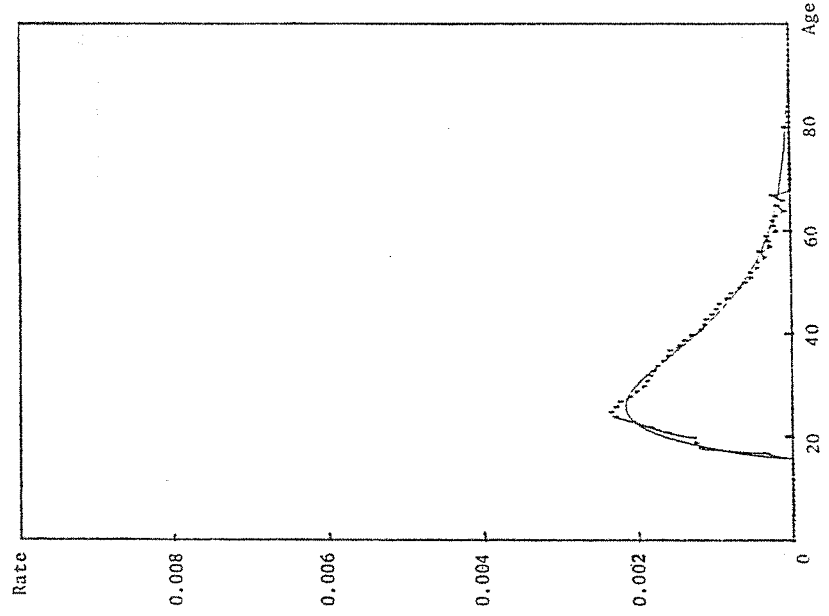

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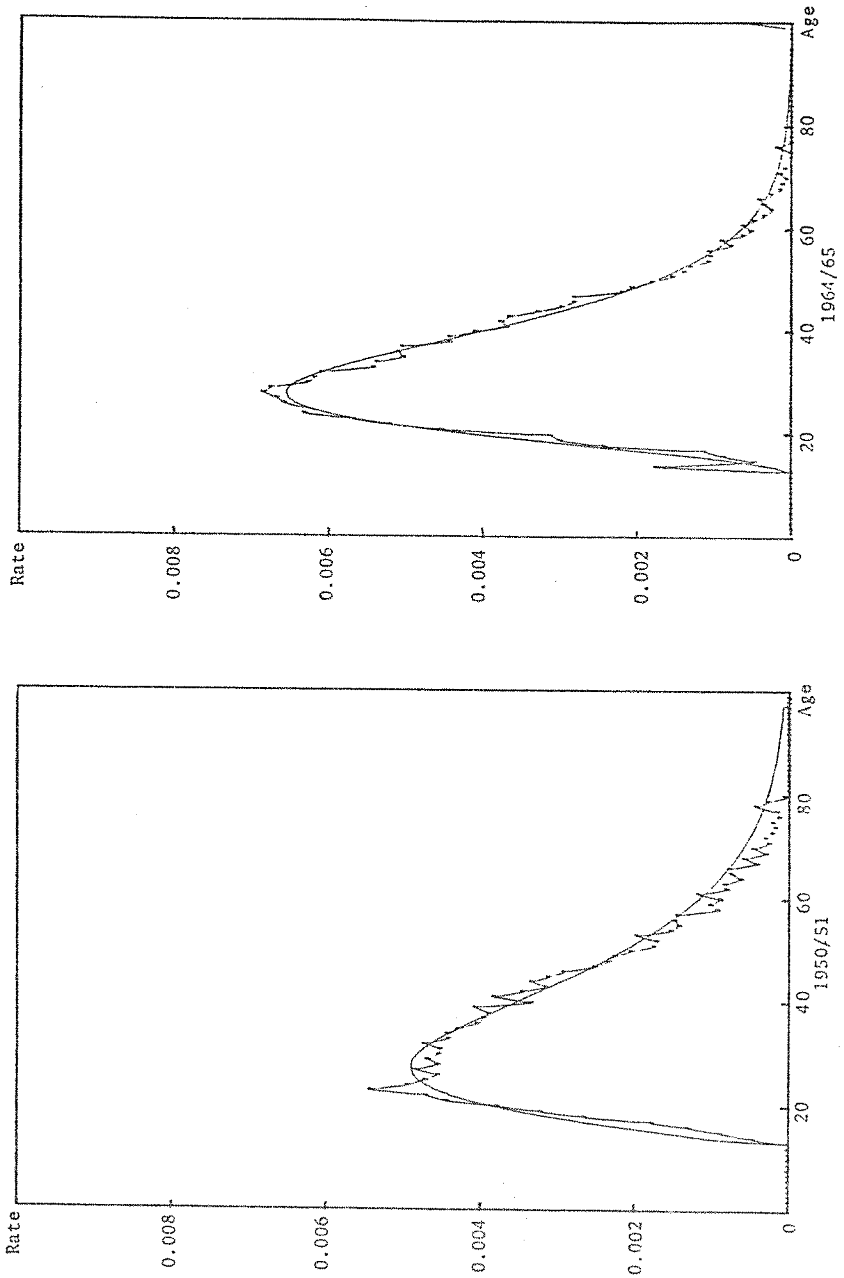
FIGURE 3

TYPICAL AGE DISTRIBUTIONS OF AGE SPECIFIC RATES OF DIVORCE FOR AUSTRALIAN FEMALES AND THEIR GAMMA APPROXIMATIONS, 1921/22, 1950/51 AND 1964/65

HISTORICAL

APPROXIMATED

FIGURE 3 *continued*



After Williams (1979).

3. The Interface with ORANI and MACRO

In discussing the interfaces it is convenient to start with the largest of the models, ORANI. Being in the Johansen (1960) family, ORANI's final form in simulation mode is linear in logarithmic differentials, and may be written :

$$y_o = A_o z_o , \tag{11}$$

where y_o and z_o may be thought of as the proportional changes in the endogenous and exogenous variables respectively. Although the structural form of ORANI recognizes many thousands of endogenous variables, the solution method involves 'substitution out' of all but about 300 of these. Other endogenous variables whose solution values are required are subsequently recovered by the process of back solution. The exogenous variables, which include world prices of those traded goods with respect to which Australia is a small country, number approximately one thousand.

There are technical problems associated with interpreting the timing of events in a comparative static model such as ORANI, and in reconciling this timing with that of a macro model fitted to quarterly data. These problems are dealt with at a technical level by Cooper and McLaren (1980), and more heuristically by Powell (1980a) : they will not be gone into here. For our purposes it will suffice to note that a transform of our MACRO model can be derived to correspond to the same time frame as ORANI; its final form in simulation mode can be written in similar format to (11); that is

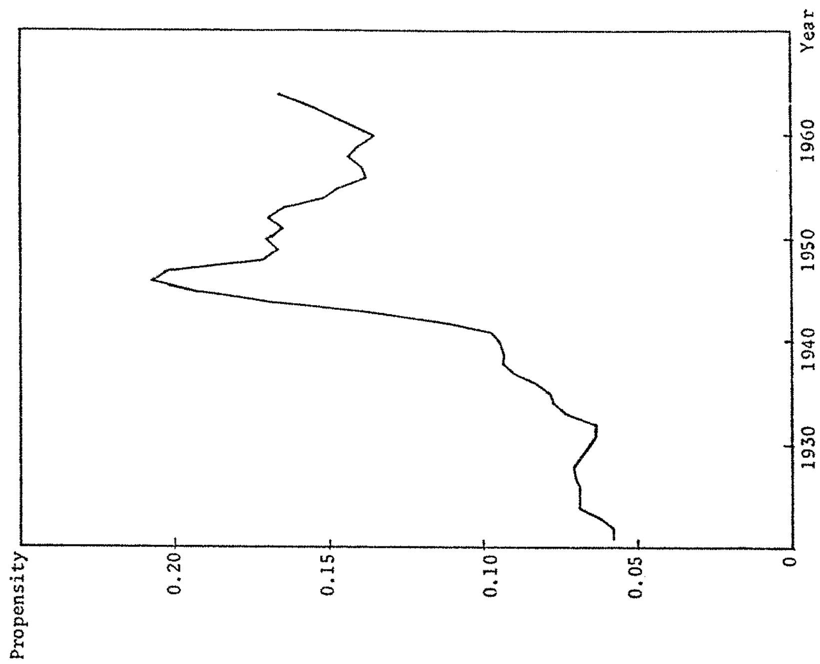
To obtain estimates of the response of the supply of hours worked in different occupations via equation (8), data of the type given in Tables 2 and 3 suffice. It is of course necessary to know the age, sex, marital status and occupational distribution of the workforce. These are to be supplied by the demographic core and by the occupational disaggregation modules discussed above. There is scope for forging further links between these three segments of BACHUROO via the role of family timing and size on the workforce participation of married females. In terms of the labour-leisure choice paradigm, increased labour force participation of married women would show up in the form of an 'as if' decline in the utility parameter γ_L applicable to this group.

At the date of writing the estimation of the labour-leisure choice module is complete. The finding that $\beta_L = 0$ for married men, however, is worrying. While the idea that this parameter would be lower for married men than for married women and for single people is plausible, in some long run sense β_L must exceed zero. That is, we would expect married men to take out at least some small part of rising living standards in increased leisure. Over the sample period 1964-65 to 1975-76 it is estimated by Tulpulé (1980 a) that married men with a non-working wife decreased their average hours of work by 2 per cent; and that those with working wives actually increased their average hours by 1½ per cent. While a host of technical problems might account for the anomaly, it is unlikely that respecification and re-estimation will improve matters unless the quantity and quality of the available data can be increased.[1]

1. In the sample data, average hours worked by married males with working wives are about six per cent below those worked by married males whose wives are not in the workforce. Insofar as rising male wage rates are correlated with increased female labour force participation, therefore, there is some negative association between hours worked by males and their rates of pay.

FIGURE 4a

INDEX OF PROPENSITY TO DIVORCE FOR AUSTRALIAN FEMALES, 1921/22 TO 1964/65



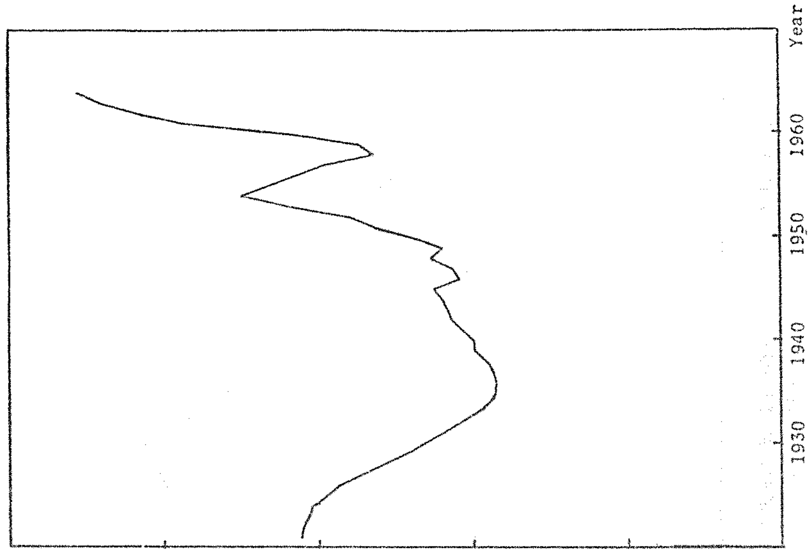
continued ...

FIGURE 4

THE PARAMETERS OF THE APPROXIMATED AGE DISTRIBUTIONS OF AGE SPECIFIC RATES OF DIVORCE FOR AUSTRALIAN FEMALES, 1921/22 TO 1964/65

FIGURE 4c

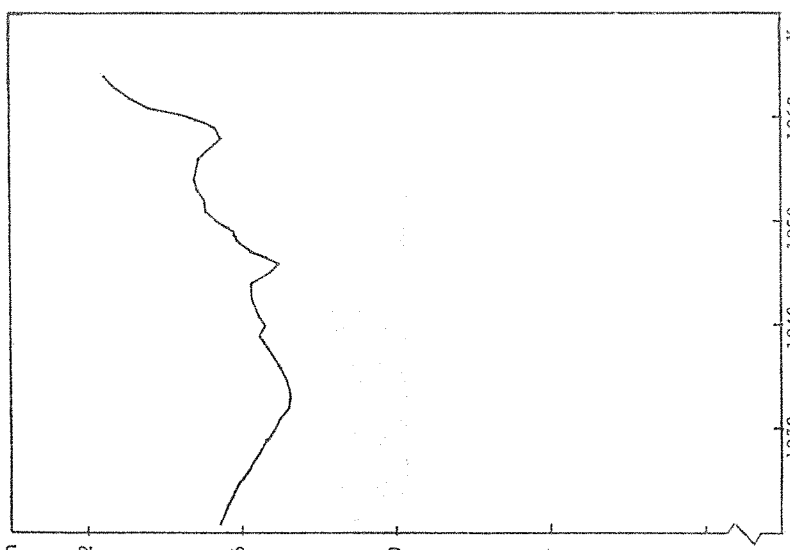
VARIANCE OF AGE AT DIVORCE FOR AUSTRALIAN FEMALES 1921/22 TO 1964/65



After Williams (1979).

FIGURE 4b

MEAN AGE AT DIVORCE FOR AUSTRALIAN FEMALES 1921/22 TO 1964/65



qualitative terms, the schedule defined by (10.1) and (10.2) would look like Figure 6b. To obtain groups of workers displaying a reasonable degree of homogeneity with respect to the offer curves confronting them, the nine occupational groups in Table 1 are further cross classified by age (junior, adult) and by sex. The parameters Θ_o, Θ_1 and Θ_2 are then estimated from cross sectional evidence. An example of these estimates is shown in Table 3.

Table 3 : Estimated Parameters of Hours/Earnings Offer Curves for Junior Males by Occupation, 1975-76

	Occupation	Θ_o Basic Hourly Wage Rate ($/hr)	Θ_1 Overtime Progression	Θ_2 Standard Hours (hrs / wk)
1.	Professional White Collar [a]	-	-	34.97
2.	Teachers and Lecturers [a]	-	-	31.41
3.	Skilled White Collar	2.4542	0.026410	36.04
4.	Semi and Unskilled White Collar	2.2867	0.005690	38.82
5.	Skilled Blue Collar - Metal and Electrical	2.1739	0.010976	39.43
6.	Skilled Blue Collar - Building	2.3252	0.008642	39.42
7.	Skilled Blue Collar - Other	2.3428	0.003279	38.93
8.	Semi and Unskilled Blue Collar	2.2565	0.017835	38.70
	All Occupations	2.2538	0.013728	38.91

a Estimation not possible due to small sample size.

Source : Tulpulé (1980 b).

Table 2 : Estimates of Marginal Leisure Preference Parameters, β_L, for Different Types of Workers

Worker Type	Estimated β_L (c)
1 Married male with working wife (a)	0
2 Working wife	0.2743 (49.98)
3 Married male with non-working wife (b)	0
4 Single male	0.2760 (27.56)
5 Single female	0.2879 (28.96)
Total workforce	0.2436

(a), (b) Constrained estimate. In absence of constraint, estimated values would have been -0.0443 and -0.1041 respectively.

(c) Ratio of parameter estimate to estimated asymptotic standard error shown in parenthesis.

Source : Tulpulé (1980 a), p. 37.

The functional form adopted by Tulpulé (1980 b) for the hours/earnings offer curves is

(10.1) $$G(H) = \Theta_o H, \quad \text{when } H \leqslant \Theta_2 ,$$

and

(10.2) $$G(H) = \Theta_o H + \Theta_1 (H - \Theta_2)^3 , \quad \text{when } H > \Theta_2 ,$$

in which G(H) is the after-tax weekly wage packet when H hours per week are worked, Θ_o is the after-tax hourly wage rate up to standard hours Θ_2 per week, and Θ_1 is the overtime progression parameter. In

structure. Estimates of the labour force participation rates are among the behavioural variables modelled in [the econometric model], and when these are combined with the population estimates, the demographic core provides estimates of the total Australian labour force."

At the date of writing, operational prototypes of each component of the demographic core shown in Figure 2 exist and are documented. The econometric models of family formation, fertility, and labour force participation (Filmer and Silberberg (1977)), and of household headship (Williams and Brooks (1978)) are at the respecification and re-estimation stage. Illustrative projections with the demographic core in stand-alone mode are the next priority.

2.2 Occupational Disaggregation

Given the size of the workforce, what could we expect its occupational composition to be at any given set of wage relativities, if people were able to locate themselves in the most preferred occupations for which they are formally qualified? The answer to this depends on the length of run envisaged. In the annual framework used in BACHUROO, one takes the educational endowments as given. In the longer run, individuals and the (largely public sector) education system can vary the skill mix. The lack of a suitable data base makes modelling the education system in Australia extremely difficult.[1] At least for the foreseeable future, the throughputs of the educational sector will be treated exogenously.

1. To obtain even an eleven year series of Australian student statistics on a compatible basis required a major input by the project team itself in primary data compilation and editing. See Craigie (1980).

The flavour of our approach to occupational disaggregation can be illustrated by Williams' (1980) treatment of within-year inter-occupational mobility. Net transfers into the j^{th} occupation desired by appropriately qualified people currently in the workforce are denoted $SM_{.j}$, where $j = 1, \ldots, 9$ refers to the occupational split shown in Table 1.[1] The net desired flow of these transferees, at the given conditions of employment, from occupation i to occupation j is SM_{ij}. Thus, by construction

$$(2) \qquad - SM_{ij} \equiv SM_{ji} \quad ,$$

and

$$(3) \qquad SM_{.j} \equiv \sum_i SM_{ij} \quad .$$

Given the skill endowments of the workforce at the beginning of the year, there exists a transformation frontier defining attainable occupational mixes. The paradigm adopted by Williams assumes that year-to-year movements in the desired occupational mix maintain equilibrium in the sense that the certainty-equivalent wage bill is maximized in the light of the prevailing expected certainty-equivalent occupational wage relativities $\{R_j\}$ (which are taken as predetermined).[2]

---

1. Here "desired" means desired by those who would transfer if the opportunity became available, and who are formally qualified to make the transfer. In the case of a potential transferee to two or more occupations other than the one currently occupied, only the most preferred transfer is counted in $SM_{.j}$.

2. Here 'certainty equivalent' wage rate for occupation j means the actual after tax hourly wage rate in j multiplied by 1 minus the occupation-specific unemployment rate. "Expected" operationally implies that actual lagged data are used.

and finally,

(vi) the estimation of the offer curves isolated under (iv) .

In the work by Tulpulé (1980 a,b) which is now described, the functional form of the utility function adopted is Klein-Rubin, i.e.,

$$(9) \qquad u = \sum_{i=1}^{n} \beta_i \, \ell n(x_i - \gamma_i) + \beta_L \, \ell n(L - \gamma_L) \quad ,$$

in which the betas and gammas are parameters. The arguments of this function are (n -1) commodities, savings (whose associated gamma is zero), and 'leisure' L consumed.[1] The groups of workers distinguished are :

(a) married males with working wives ;

(b) married working females ;

(c) married males with non-working wives ;

(d) single males ;

(e) single females .

The gamma parameters are chosen in such a way as to be compatible with international evidence on the Frisch parameter (Lluch, Powell and Williams (1977)). Time-series evidence is then used to estimate the marginal leisure preference parameters, β_L . The estimates obtained for the different groups of workers are shown in Table 2.[2] These values are to be interpreted as the fraction of an additional dollar of 'full income' (i.e., of labour plus non-labour income, plus the imputed value of leisure) which would be 'spent' in the implicit purchase of one's own time by declining to work additional hours.

---

1. Howe (1975) has shown that introducing savings directly into the utility function with unit price and zero gamma provides a heuristic device for the derivation of Lluch's (1973) extended linear expenditure system, thus giving the maximization of (9) an intertemporal interpretation.

2. In the case of married males, unconstrained estimates of β_L turn out to be negative (see footnotes to Table 2). In the raw data this is reflected by a very small response in hours worked by married males, despite a substantial increase in income. The matter is taken up below (p. 28).

λ_α is the derivative of the marginal utility of income with respect to non-labour income, α ; $y_{o\alpha}$ is the derivative of the demand for 'leisure' with respect to non-labour income ; ψ_Θ is the vector of derivatives of the after tax marginal wage rate with respect to the parameters Θ ; u_{oo} is the second derivative of the utility function with respect to the amount of 'leisure' consumed ; ψ' is the derivative of the marginal wage rate with respect to hours worked ; u_o is the vector of derivatives with respect to the quantities of commodities consumed of the marginal utility of 'leisure;' and U is the principal sub-matrix of the Hessian of the utility function corresponding to arguments other than 'leisure.'

To apply (8) empirically, the following steps are necessary :

(i) the adoption of a particular functional form for the utility function ;

(ii) the identification of groups of workers whose utility parameters could reasonably be supposed to be homogeneous ;

(iii) the adoption of a particular functional form for the hours/earnings offer curves ;

(iv) the identification of groups of workers who could reasonably be assumed to face the same hours/earnings offer curves ;

(v) the estimation of the relevant utility parameters for the groups isolated under (ii) ;

This basic mechanism is illustrated in Figure 5. Q_1 and Q_2 respectively are the supplies of workers in occupations 1 and 2. The movement from A to B is seen as a response to a change in the ratio of certainty equivalent occupational wage rates , R_1/R_2 , from tan Θ_A to tan Θ_B . Changes in certainty equivalent wage rates, therefore, are identified with shifts around the transformation frontier.

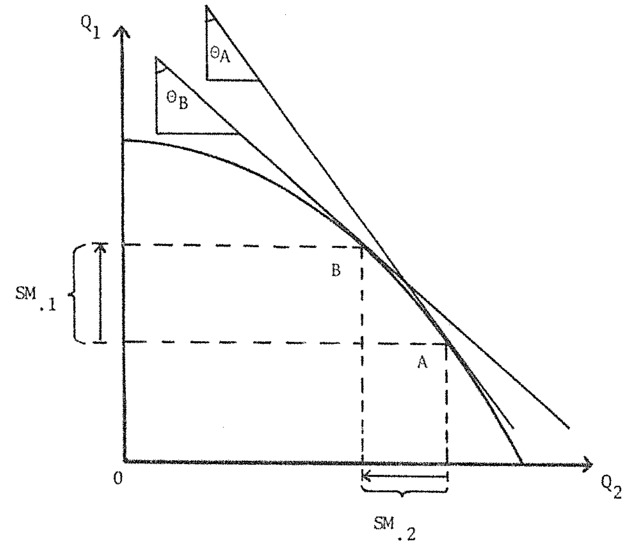


Figure 5 : Occupational transformation frontier in 2-occupation case. Initially the certainty equivalent occupational wage ratio (R_1/R_2) is tan Θ_A . This ratio then changes to tan Θ_B, resulting in a new equilibrium occupation mix at B .

It is supposed that apart from certainty equivalent wage rates $\{R_1, \ldots, R_9\}$, there are K other explanatory variables $\{N_1, \ldots, N_K\}$ which generate changes in occupational labour supplies $\{Q_1, \ldots, Q_9\}$. These other explanatory variables are to be identified with shifts of the occupational supply frontier in Figure 5 rather than with shifts around it. In the absence of suitable data, the $\{N_k\}$ in the empirical work are proxied by log-linear trends. In pragmatic spirit, it is assumed that a double-log functional form,

(4) $$d \log Q_j = \sum_{i=1}^{9} \eta_{ji}\, d \log R_i + \sum_{k=1}^{K} \varepsilon_{jk}\, d \log N_k ,$$

will yield an adequate approximation to the supply functions. Parametric restraints induced by assumptions concerning the functional form of the transformation frontier reduce the 81 wage coefficients $\{\eta_{ji}\}$ to a more manageable number. In the case of the CRETH (Dixon (1976)) transformation frontier, these 81 coefficients are reduced to just nine transformation parameters (Craigie, Parham and Ryland (1979)). In the case of the extremely meagre data base available for fitting (4), however, nine parameters were too many; consequently Williams (1980) fitted a CET (constant elasticity of transformation) transform of (4). Under this specification, the 81 coefficients η_{ji} can all be expressed as functions of just one unknown transformation elasticity, τ. Using the approximation

(5) $$d \log Q_j \doteq SM_{.j}/Q_j$$

and using the CET postulate to constrain the η_{ij} coefficients to be

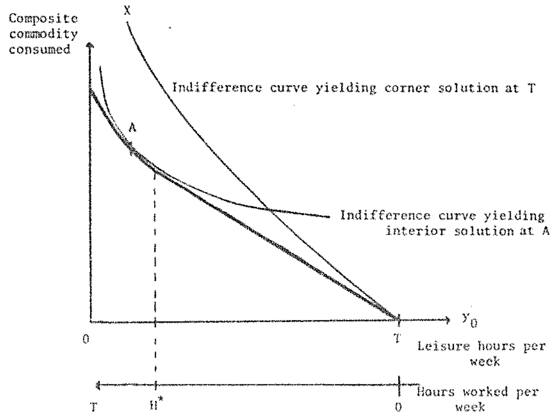


Figure 7 : The heavy line is the budget constraint of a consumer/worker who faces a ψ schedule which is flat from 0 to H^* hours, but which then rises. The relative convexity of this line and of the indifference map determines whether the solution point is in the interior of $[0, T]$ or at a corner (after Powell (1980b)).

y_o denoting broadly defined 'leisure' (i.e., time not spent in paid employment), the fundamental equation from which elasticities of hours supplied can be inferred (Powell (1980b)) is,

(8) $$y_{o\Theta} = y_{o\alpha}\left[G_\Theta - \frac{\lambda}{\lambda_\alpha} y_{o\alpha}\, \psi_\Theta\right] + \frac{\lambda \psi_\Theta}{u_{oo} + \lambda\psi' - u_o^T U^{-1} u_o} ,$$

in which $y_{o\Theta}$ is the vector of the slopes of the demand for 'leisure' (equal to the negative of the slopes of the supply of hours) with respect to the parameters Θ of the hours/earnings offer curve; G_Θ is the vector of derivatives of after tax earnings with respect to the parameters Θ; λ is the marginal utility of (optimally spent) income;

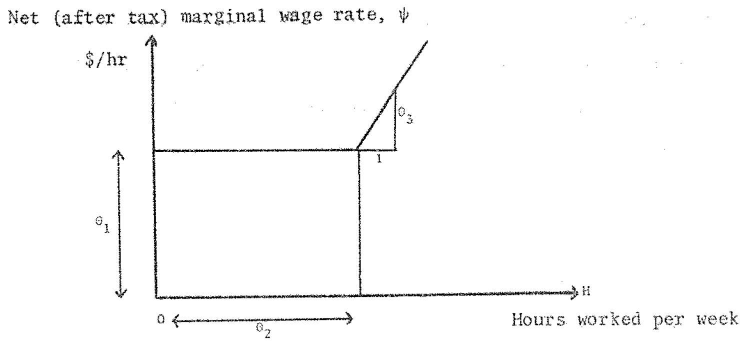


Figure 6a : A simple earnings/hours schedule with parameters θ_1 ($/hr, basic hourly wage rate), θ_2 (hours, defining the standard working week), and θ_3 ($/hr/hr, steepness of the overtime progression). G(H) is the area under the curve. (After Powell (1980b).)

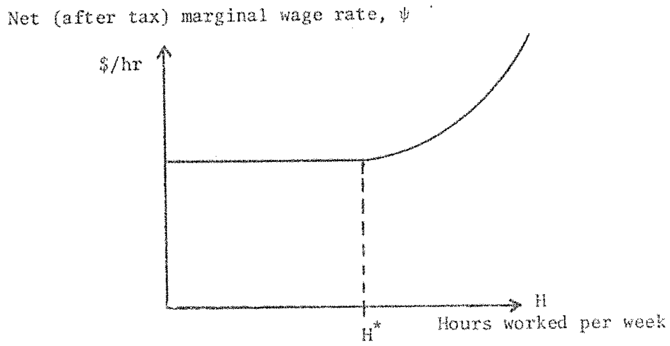


Figure 6b : Hypothetical earnings/hours schedule in which the after-tax marginal hourly wage rate is constant up to H^* hours per week, and thereafter steadily increases.

$$(6) \qquad \eta_{ij} = \tau S_j \quad \text{for all } i \quad (j \neq i) ,$$

and

$$(7) \qquad \eta_{jj} = -\tau(1 - S_j) \qquad [\text{where } S_j = \text{share of occupation } j \text{ in the certainty equivalent wage bill}] ,$$

the best estimate obtainable from the data is $\hat{\tau} = -1.3$ (t = 3.6). Via equations (6) and (7) this estimate enables the $\{\eta_{ij}\}$ to be estimated. [1]

The remaining element of flexibility in the occupational mix not captured in Williams' work is that due to the flexibility of new workforce entrants. Although when an individual commits himself to a particular stream of higher education and/or vocational training he may have in mind a preferred occupation which he would like to enter upon graduation, he may nevertheless settle for another occupation if jobs are easier to find in it and/or if this other occupation commands higher relative wages at graduation than were expected at the time the educational decision was taken. His flexibility will be limited only by the formal requirements for entry into the various occupations. Thus the work planned by Craigie, Parham and Ryland (1979), but not yet implemented, uses an approach similar to the one described above. In that the proposed work attempts to identify the shift variables $\{N_1, \ldots, N_k\}$ with the

---

1. This abbreviated account, it should be noted, has not dealt with the extremely difficult problem of generating data on the supply of transferees, $\{SM_{.j}\}$ as distinct from the actual number of transfers. Given the undoubted existence of a non-market clearing wage structure in one of the two years for which data were available, the natural starting point was Fair and Jaffee (1972). Strong priors on labour demand plus data on unemployment were essential ingredients in development of the $\{SM_{.j}\}$. Readers requiring further details should consult Williams (1980).

current levels of stocks of various kinds of human capital, the approach is somewhat more ambitious. For the reasons mentioned in the introduction to this section, the $\{N_k\}$ themselves, being determined by the initial stocks of people of given educational levels as updated by the throughputs of the educational system, are to be treated as exogenous.

At the date of writing, empirical work on occupational mobility within the workforce is complete in the sense that the information content of the currently available stock of data has been exhausted; the quality of the estimates could doubtless be improved if and when better and/or more data were to become available. A data base and a theory to extend this work to cover all elements of occupational flexibility within the workforce are available : currently professionals to do the work are not. It is hoped that this situation can be rectified within the next six months.

2.3 Leisure and Hours Worked

Sections 2.1 and 2.2 above have described our approaches to the determination of the size and age structures of the population and workforce, and to the occupational composition of the latter. What remains to be discussed is the endogenization of the number of hours supplied by members of the workforce having a given occupational affiliation.

The framework adopted is the standard neo-classical labour-leisure choice paradigm in which the shadow price of 'leisure' is the wage rate foregone for an additional hour of work voluntarily declined. [1]

1. Early references include Robbins (1930), Paish (1941), and Gilbert and Pfouts (1958). For more recent contributions see Betancourt (1973), Abbot and Ashenfelter (1976), Phlips (1978) and Barnett (1979).

Because of the increasing importance of part-time work and of progressive income tax scales and penalty rates for overtime, the required paradigm cannot, as in the early literature, take the after-tax marginal wage rate as an exogenous constant which is independent of the number of hours worked. Powell, Tulpulé and Filmer (1977) extended the standard framework to allow the after-tax marginal wage to be an arbitrary twice differentiable function of the number of hours worked. This was in the context of a Klein-Rubin utility function. Burtless and Hausman (1978) worked with an arbitrary, not necessarily convex, budget constraint, and with a particular utility function (namely, the one implied by a constant elasticity labour supply function). Woodland and Wales (1979) also considered an arbitrary budget constraint allowing for endogenous variations in the shadow price of leisure. Their utility specification was CES. Finally, Powell (1980b) gave a general treatment of the problem in which both the hours/earnings offer curve[1] and the utility function are arbitrary. This last-mentioned paper covers all cases of movements in the supply of hours of an individual which are induced by changes in the parameters of the hours/earnings curve and/or of the utility function, except those changes involving discrete jumps and corner solutions. The extension of the conceptual framework to handle the latter is trivial; its empirical implementation, however, involves formidable difficulties.

The basic ideas involved are illustrated in Figures 6 and 7. Figure 6b is the after-tax marginal hourly wage rate schedule derived from a hypothetical hours/earnings offer curve which rewards overtime at steadily increasing penalty rates. This induces the non-convex budget constraint shown in Figure 7. Non-corner solutions are generated by points of tangency between indifference curves and the budget constraint. With

1. The hours/earnings offer curve relates after-tax labour income per week to the number of hours worked.