



IMPACT OF DEMOGRAPHIC CHANGE ON INDUSTRY STRUCTURE IN AUSTRALIA

A joint study by the Australian Bureau of Statistics, the Department of Employment and Industrial Relations, the Department of Environment, Housing and Community Development, the Department of Industry and Commerce and the Industries Assistance Commission

EDUCATIONAL ATTAINMENT
AND OCCUPATIONAL SUPPLY :
A THEORETICAL OUTLINE

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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hence,

$$\lambda = \sum_{i=1}^n S_i^* W_i + I - \sum_{i=1}^n S_i^* Q_i, \quad (A7)$$

where

$$S_i^* = \frac{\hat{S}_i}{\sum_{j=1}^n S_j} = \frac{S_i}{(r_i - 1)}$$

Substituting (A7) into (A2) gives

$$(r_i - 1) L_i = W_i - \sum_{j=1}^n S_j^* W_j + (r_i - 1) I - r_i Q_i + \sum_{j=1}^n S_j^* Q_j,$$

hence

$$L_i = \frac{1}{r_i - 1} \left[W_i - \sum_{j=1}^n S_j^* W_j \right] + I - Q_i - \frac{1}{r_i - 1} \left[Q_i - \sum_{j=1}^n S_j^* Q_j \right], \quad (A8)$$

where

$$S_i^* = \frac{\frac{W_i L_i}{r_i - 1}}{\sum_{j=1}^n \frac{W_j L_j}{r_j - 1}} = \frac{\sum_{q=1}^n \frac{W_{iq} L_{iq}}{r_{iq} - 1}}{\sum_{j=1}^n \frac{W_j L_j}{r_j - 1}}. \quad (A9)$$

The equivalence of (A8) and (A9) to (5) and (6) is easily seen.

by

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1. BACKGROUND

There have been three major areas of development in neoclassical analysis of labour supply.¹ In the first area, initiated by Robbins (1930), the supply of labour is analysed as the antithesis to the demand for leisure. The main focus of applied work in this area is to determine the relative strengths of (negative) wage substitution and (positive) income effects on the demand for leisure, with consequent implications for the supply of additional hours.

Two major extensions of the price-theoretic approach have emanated from the National Bureau of Economic Research (NBER). The first extension, attributed mainly to Jacob Mincer, recognizes interdependence in labour supply decisions by giving consideration to secondary workers in the context of a family unit. The main empirical work in this stream concerns the labour force participation of married women.²

* Without implicating them in any way, we thank our BACHURRO colleagues and in particular Alan Powell and Peter Dixon for their helpful suggestions and comments at the various stages of development of this paper.

1. A major body of criticism of the neoclassical approach to labour supply is outlined in Cain (1976).
2. See Mincer (1963). Other major works in this area include Cain (1966) and Bowen and Finegan (1967).

2.

The second extension, with perhaps more antecedents, evolved into the Human Resources approach of the NBER, in which labour supply is considered as an adjunct to a decision to invest in human capital through education, migration, on-the-job training, job search and so on. This development arose from the inadequacy of "leisure" as the only alternative to "work" for some analyses. Major contributions in this area have been provided by Shultz (1961), Mincer (1958), and Becker (1975).¹

Thus, with some over-simplification, the three main orthodox approaches to labour supply are a short run analysis of additional hours, a medium term analysis of participation rates of secondary workers, and a longer run analysis of occupational choice where increases in lifetime earnings provide returns on investments in human capital.

This paper remains nested well within the traditional price-theoretic framework and, insofar as it addresses the relation between occupational choice and education, it is aligned most closely to the human capital approach. However it does seek to introduce a change in focus, by concentrating on a different stage of the decision making process. Differences between this paper and traditional approaches are outlined below.

First, this paper is concerned neither with the short run decision on labour/leisure choice (additional hours),² nor with the lifetime earnings horizon³ of the human capital approach. Instead, it

1. Mincer (1970) provides a survey of some aspects of the human capital approach.
2. Persons are used as the unit of measurement rather than hours.
3. A lifetime horizon is not a necessary feature of the human capital approach. However, the planning horizon assumed is normally the very long run.

Substituting (A4) into (A3) gives

$$\sum_{j=1}^n x_j \left[\frac{Q_j L_j}{L} \right]^{x_j} \left[\sum_{i=1}^n (Q_i + L_i - \dot{L}_i) S_i \right] = 0,$$

hence

$$\sum_{i=1}^n S_i \dot{Q}_i + \sum_{i=1}^n S_i L_i - \dot{L} = 0, \tag{A5}$$

since $\sum_{i=1}^n S_i = 1$.

From (A2),

$$\dot{W}_i + \dot{L} - \dot{Q}_i = \dot{\lambda} + (r_i - 1)(Q_i + L_i - \dot{L})$$

by adding $(\dot{L} - \dot{Q}_i)$ to both sides.

Multiplying through by $\frac{S_i}{r_i - 1}$ and summing over products

gives

$$\sum_{i=1}^n \frac{S_i \dot{W}_i}{r_i - 1} + \dot{L} \sum_{i=1}^n \frac{S_i}{r_i - 1} + \sum_{i=1}^n \frac{S_i \dot{Q}_i}{r_i - 1} = \dot{\lambda} \sum_{i=1}^n \frac{S_i}{r_i - 1} + \sum_{i=1}^n S_i \dot{Q}_i + \sum_{i=1}^n S_i L_i - \dot{L}. \tag{A6}$$

Substituting (A5) into (A6) gives

$$\sum_{i=1}^n \hat{S}_i \dot{W}_i + \dot{L} \sum_{i=1}^n \hat{S}_i - \sum_{i=1}^n \hat{S}_i \dot{Q}_i = \dot{\lambda} \sum_{i=1}^n \hat{S}_i,$$

where

$$\hat{S}_i = \frac{S_i}{r_i - 1};$$

Appendix A

3.

From the Lagrangian formed from (1) and (4), the first order conditions can be expressed as :

$$W_i = \lambda r_i \begin{pmatrix} Q_i & L_i \\ Q_i & L_i \\ L_i & L_i \end{pmatrix} r_i^{-1} \quad (A1)$$

(n equations)

and

$$\sum_{i=1}^n \begin{pmatrix} Q_i & L_i \\ Q_i & L_i \\ L_i & L_i \end{pmatrix} r_i = 1 \quad (4)$$

(1 equation)

This system may be linearized by expressing these

equations in proportional change form to give :

$$\dot{W}_i = \dot{\lambda} + r_i (\dot{Q}_i + L_i - L_i) - L_i \quad (A2)$$

and

$$\sum_{i=1}^n r_i (\dot{Q}_i + L_i - L_i) \begin{pmatrix} Q_i & L_i \\ Q_i & L_i \\ L_i & L_i \end{pmatrix} r_i = 0 \quad (A3)$$

The elimination of $\dot{\lambda}$ is performed in several steps.

From (A1),

$$\text{Let } S_i = \frac{W_i L_i}{\sum_{j=1}^n W_j L_j} = \frac{\lambda r_i \begin{pmatrix} Q_i & L_i \\ Q_i & L_i \\ L_i & L_i \end{pmatrix} r_i^{-1}}{\lambda \sum_{j=1}^n r_j \begin{pmatrix} Q_j & L_j \\ Q_j & L_j \\ L_j & L_j \end{pmatrix} r_j} \quad (A4)$$

continued

is cast in a medium term framework of adjustments to annual prices (wages). Second, the framework developed is used to analyse the education/occupation relation for the workforce as a whole rather than for an individual. More specifically, we seek to determine the influence of wages and educational attainment on the distribution of the workforce according to skill category.

Third, the paper is not concerned with measuring the rates of return on education or with the stage of decision-making at which an education stream is selected (perhaps on the basis of perceived relative returns on human capital investment) with a view to a career path. Rather, it is concerned with a later stage of decision-making concerning the occupational possibilities after educational qualifications have been attained. We examine the influence of wage variables on the occupational choices of the workforce, for given attainments in education.

Fourth, we do not impose the rigid relationship between educational attainment and occupational choice, which characterizes the manpower requirements approach. Whereas the manpower requirements approach distributes changes in educational attainments to occupations according to fixed coefficients, we introduce greater flexibility. We allow changes in educational attainments to influence labour supplies in two ways. In the first way, changes in educational attainments have occupation specific influences on labour supplies by changing the bias in the set of occupational possibilities towards certain occupations.¹ For example, a relative expansion of

1. The fixed coefficients manpower requirements approach is a highly specialized case of this occupation-specific effect.

of sources, and from this work, we propose to use the categories, Any Secondary, Trade, Technician, Diploma, Degree. Data are available from this study for the period 1966-1977.

Employment by occupation data are available for the same period in special tabulations of the Labour Force Survey provided by the Australian Bureau of Statistics (ABS).¹

Wage information presents more problems. Annual income information classified by occupation can be obtained for the financial years 1968/69 and 1973/74 from special tabulations of the ABS Income Distribution Surveys.² Weekly earnings data are available from special tabulations of the ABS surveys of Earnings and Hours.³ Other relevant information is likely to come from published sources such as award rates for occupations in the ABS publication, Wage Rates (ABS(e)).

Obviously, considerable work will have to be undertaken in the pre-estimation phase to compile a data series on wages which approximates definitional consistency. Further work is required to explore other data sources and to transform them to a consistent definitional basis using, for example, the two major annual income data points (from the Income Distribution Surveys) as benchmarks.

Once the data series have been collated, we can proceed with estimation of (16) and possibly other functional forms (e.g. CFT and CONDETH) as previously envisaged.⁴

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1. See Australian Bureau of Statistics (a) for published statistics. A description of the special tabulations is given in Parham and Ryland (1978b).
 2. See Australian Bureau of Statistics (b) and (c) and Parham and Ryland (1978b).
 3. See Australian Bureau of Statistics (d).
 4. See Parham and Ryland (1978a).

tertiary degrees awarded may bias the occupational possibilities more towards professional workers relative to skilled blue collar workers. In the second way, changes in educational attainments lead to equi-proportional (i.e. neutral) changes in all occupational supplies.¹ The final occupational composition resulting from a combination of these two kinds of changes depends on the resulting overall labour capacity, the bias in occupational possibilities, the ease of transformation between occupations and finally the relative wages.

The specific aims of this paper are, first of all, to explore in more detail, but still at a theoretical level, the analytical framework for the estimation of skill transformation parameters foreshadowed in Parham and Ryland (1978a). In that paper, it was pointed out that demand-side skill substitution is perhaps ill-considered in isolation from supply-side transformation. The second aim, derived more from an interest in the development of the demographic-labour supply model, BACHUROO,² is to explore in part the linkages between the education sector and the labour force.

In the next section, we provide a brief outline of the theoretical model - - the conceptual framework and its limitations. In section 3, we provide a diagrammatic representation of the mechanisms of the model. In section 4, we tackle the specification of mathematical relationships, concentrating mainly on the education linkages. Finally, we provide in section 5 our proposals for the forthcoming estimation phase.

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1. The neutral component of change can be related to the notion of separability between inputs (educational attainments) and outputs (occupational supplies) - - see Hasenkamp (1976) and Vincent, Dixon and Powell (1978), pp. 7-8.
 2. For an outline of BACHUROO, see Powell (1977).

qualifications and some professional occupations, then the corresponding gamma parameter would be set to a relatively large absolute value.

Assuming a well behaved error structure for the supply equations, the system can be submitted to the RESTIMUL¹ package for estimation. An estimation framework well suited to this sort of system is given in Ryland and Parham (1978). The system as it stands requires estimation of n transformation parameters and up to $n \times (m-1)$ gamma parameters.²

A desirable extension of (16) would be to allow various forms of flexibility in the transformation possibilities. An obvious candidate for alternative specifications is to allow constant differences of elasticities of transformation (CONDETH) instead of constant ratios of elasticities of transformation (CHETH). Either of these specifications requires estimation of n transformation parameters. A special case of these specifications would be to allow constant elasticity of transformation (CHT) possibilities, involving the estimation of only one transformation parameter.

We propose to maintain our focus at a five occupation disaggregation of the workforce, in keeping with earlier labour demand oriented work on estimation of skill substitution elasticities.³ The major occupational groups of interest are Professional, Skilled White Collar, Unskilled White Collar, Skilled Blue Collar and Unskilled Blue Collar.

We also propose to incorporate five educational attainment categories. Craigie (1978) collated education statistics from a variety

1. See Wymer (1977).
2. Less parameters need to be estimated if zero and/or other restrictions can be imposed.
3. See Ryland and Parham (1978).

2. THE PROBLEM STATED BROADLY

We assume the existence of a representative labour supplier who is able to devote labour services contemporaneously to each occupational classification in the workforce. This supplier is representative in the sense that he/she encapsulates the behaviour of individuals on the one hand and yet faces collective constraints of entire occupations on the other.

Possible combinations of services to each occupation are combined in an aggregating function to form an aggregate index of labour services, which we term the labour capacity index. The simplest form of an aggregation function is a linear combination of the occupation supplies. But, since this assumes perfect transformability between occupations, it holds little interest in our model. Because of different substitutibilities and preferences of workers towards the various occupations, the law of increasing marginal rates of transformation applies. Thus, due to this imperfect transformability the aggregating function combining the various occupational supplies exhibits some degree of non-linearity.

The aggregating function is analogous to the production possibilities frontier of the product transformation world. We refer to the function describing the occupational supply transformation possibilities as the Skill Transformation Frontier (STF), and concentrate in this paper on three sets of its parameters. These are the transformation parameters (related to the curvature of the STF), the distribution parameters (related to the bias or skew in the STF towards certain

occupations), and the capacity index¹ (related to the distance of the STF from the origin).

Conceptually, there are many factors which affect the parameters of the STF - everything from the inherent gene pool of the population to social conditioning processes. For instance, the capacity index is related in some general fashion to the size of the workforce. This in turn is affected by demographic factors and migration flows on the one hand, and the influence of labour/leisure/education choices on participation rates on the other. The transformation parameters reflect the occupational flexibility of the workforce and may be influenced to some degree in the very long run by overall levels and styles of education. The bias parameters reflect the preferences and suitabilities of the workforce in relation to the set of occupational possibilities. Differential changes in educational attainments would be the most important factor explaining changes in these parameters.

Although various combinations of occupational supplies are possible for given values of the parameters of the STF, only one combination will be selected. We assume that the representative agent selects that combination which, for a predetermined set of occupational possibilities (i.e. for fixed STF), maximizes labour income.

1. The capacity index is formally a parameter of the transformation schedule developed below. Although parametric from this viewpoint, the value of the capacity index varies from a transformation frontier at one point of time to the next. The choice between the terms 'variable' and 'parameter' therefore depends on one's focus and is essentially arbitrary. We have opted to term the capacity index a 'parameter'. On this convention, movements around a particular transformation schedule do not involve changes in parameters; movements of such frontiers, however, do.

5. PROPOSED STRATEGY FOR ESTIMATION

Substituting the education-capacity relationship (12) and the education-occupation bias relationship (10) into the supply equation (5) and using the restriction (15) gives the final reduced form for the system of n supply equations:

$$L_i = \pi_1 \left(\dot{W}_i - \sum_{j=1}^n S_j^* \dot{W}_j \right) + \dot{N}^c - \sum_{k=1}^m \gamma_{ik} \dot{N}_k^b \quad (16)$$

$$- \pi_1 \left(\sum_{k=1}^m \gamma_{ik} \dot{N}_k^b - \sum_{j=1}^n S_j^* \sum_{k=1}^m \gamma_{ik} \dot{N}_k^b \right)$$

Explanatory variables in the system are n wage variables and $m+1$ educational attainment variables.

As a data construction, the percentage changes in m educational attainment categories are decomposed into a uniform component, \dot{N}^c , and m discriminatory components. Since the \dot{N}^c variable is measured as the minimum percentage change across all m categories, (see 13)), by definition, one of the m discriminatory variables (derived from (8)) must have a value of zero.

At the estimation stage, it may be possible to impose further restrictions on the γ parameters. For example, one would expect the effect of an increase in university degree graduates to have a negligible effect on the supply of unskilled blue collar occupations. The gamma parameter relating these two variables could be set at zero. Similarly, if there is a strong relationship between educational attainment of a certain type and a particular occupation, such as degree

Let r be the matrix whose typical element is r_{ik} (see equation 10)). Then in the context of manpower requirements r would be a square matrix such that with suitable ordering of the rows (or columns)

$$r = -I$$

(where I is the identity matrix). This result follows from equation (5) and (10) since there exists, for the requirements approach, a unique one-to-one mapping between attainments and occupational supplies.

Whether other restrictions can be imposed outside of this special case is a matter for further investigation.

The above notions are illustrated diagrammatically in Figure 1 for a two occupation case. Combinations of supplies from each occupation are described by the Skill Transformation Frontier, labelled STF. For a given STF (i.e. for given capacity index, transformation possibilities and occupational bias), the representative agent seeks to maximize income. The optimal combination is determined by the point of tangency between the STF and the line, RL , the slope of which reflects the relative wages for the occupations. In this case, the income maximizing combination is OX labour services from occupation 1, and OY from occupation 2.

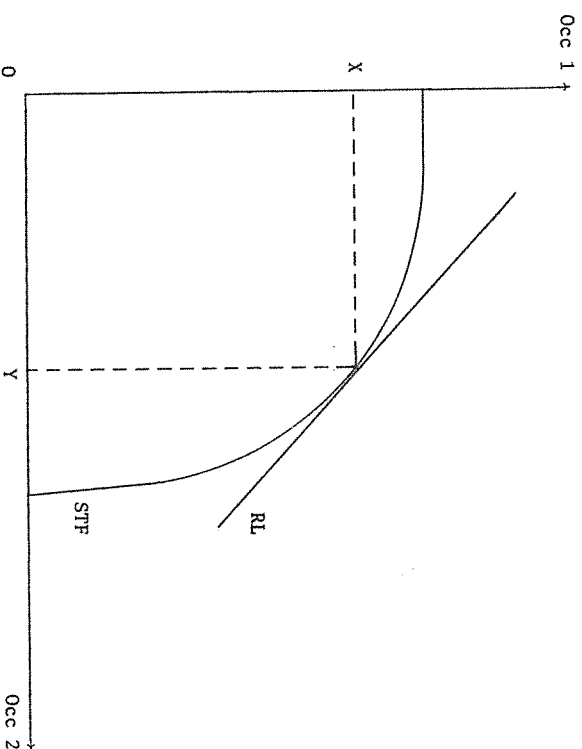


Figure 1 : The Optimal Occupational Supplies Determined by Maximization of Income Subject to an STF.

An algebraic representation of the problem can be expressed as follows:

$$\max \sum_{i=1}^n W_i L_i \quad (1)$$

subject to

$$G_{\bar{\theta}}(L_1, L_2, \dots, L_n) = 0 \quad (2)$$

where

W_i = perceived wage variable for occupation i , 1

L_i = number of people offering their labour services in occupation i , 2

$G(\cdot)$ = labour aggregation function (the STF),

$\bar{\theta}$ = set of capacity, transformation and bias parameters of the STF.

Although the parameters of the STF are affected by a myriad of factors (as mentioned above), all these effects can be captured through changes in educational attainments. This is because the educational

1. In choosing between occupations people are most likely to view the pre-tax annual earnings with some adjustment for risk of unemployment.
2. In our paradigm, the number of people offering their labour services in occupation i is determined as the product of the proportion of the representative agent's available services allocated to occupation i and a scale factor reflecting the number of people prepared to offer their labour services at the going wage rates. The latter variable, although endogenous to an overall theory of labour supply is taken as predetermined in the present paper.

components. The minimum change in attainments (the uniform component) is, in this case, in the category (or categories) producing occupation 2 skills. Thus there is no bias effect towards occupation 2. On the other hand, there are changes in excess of that uniform component in those attainment categories producing occupation 1 skills.

The final element in the specification is the imposition of some further restrictions. It seems reasonable to postulate that, in the absence of any changes in relative wages, any uniform percentage change, β , in the stocks of all educational attainments will lead to the same percentage change in all occupational supplies. That is, under these conditions,

$$\frac{\dot{N}_k}{N_k} = \frac{\dot{L}_i}{L_i} = \beta \quad \text{for all } k \text{ and } i. \quad (14)$$

As can be seen from equations (12) and (5), this requirement implies that

$$\sum_{k=1}^m \alpha_k = 1. \quad (15)$$

Further restrictions may be forthcoming from the conceptual requirement that a change in the total stock of people (offering their labour services) with various educational attainments must be matched exactly by the change in the total stock of people offering their labour services to various occupations. For example in the special case of the manpower requirements approach (i.e. zero transformation possibilities) the undermentioned restrictions would follow from this property.

The two different effects of changes in educational attainments on the STF are illustrated in Figure 5.

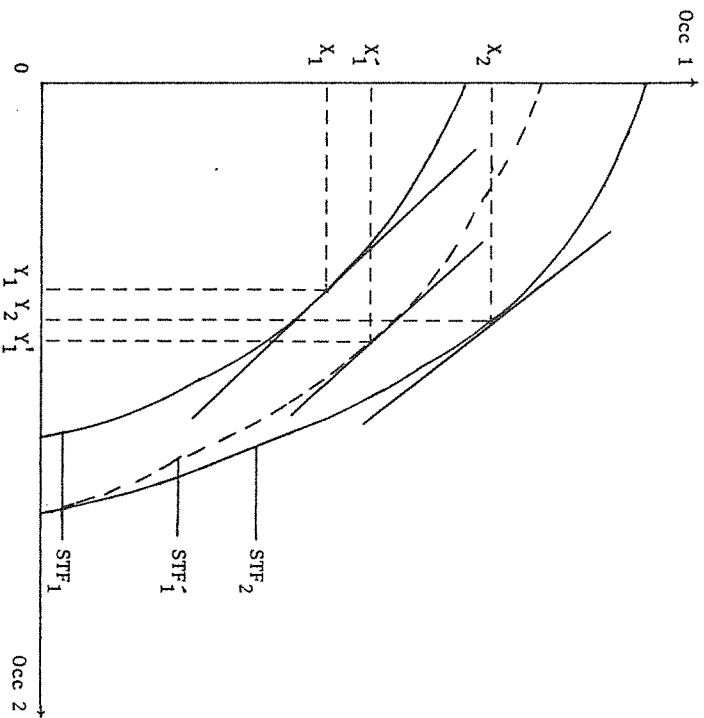


Figure 5 : Dissection of a Change in the STF into Neutral and Biased Shifts.

Due to overall changes in educational attainments, the STF shifts from STF_1 to STF_2 . This total shift can be decomposed into a neutral shift - - the shift from STF_1 to STF_1' - - and a biased shift from STF_1' to STF_2 . The neutral shift is due to the uniform component in the changes in educational attainments and the biased shift is due to the discriminatory

categories used in this model are exhaustive with respect to those people offering their labour services.¹ Thus the effects of say, migration or demographic changes on the STF are incorporated in this model via their corresponding changes in educational attainments. However it is important to note that the changes in educational attainments are exogenous to this model.²

Changes in educational attainments can have two types of effect on the parameters of the STF. They can affect the capacity parameter and the bias parameters. The time horizon implicit in this analysis is insufficient to allow changes in the transformation parameters.

Due to the exhaustiveness of the educational categories any equi-proportional change in the stocks of educational attainments will have a neutral effect on the set of occupational possibilities. That is, such a change will alter overall labour capacity without having any bias effect.

Discriminatory changes in educational attainments, on the other hand, will alter the pre-existing biases in the set of occupational possibilities. This is because each educational category has different comparative advantages in the production of the various occupational skills. For example, a relative increase in university graduates will increase the biases towards professional and skilled white collar occupations.

1. Secondary education is compulsory up to the age of fifteen years. Thus all those offering their labour services would have achieved at least some level of secondary schooling. Thus the inclusion of a residual education category "Any Secondary" makes the classification exhaustive.
2. An interesting extension of this model would be to endogenise educational attainment. This would involve the analysis of the effects on educational attainment (and hence occupational supply) of human capital investment decisions, demographic factors, migration and so on.

We propose therefore the following reformulation of the Skill Transformation Frontier in order to capture the capacity and bias effects of changes in educational attainments. We specify

$$G_{\bar{0}}(L_1, \dots, L_n) = 0 \quad (2)$$

and

$$\bar{0} = f(N_1, N_2, \dots, N_m) \quad (3)$$

where

N_k = number of people offering their labour services
with educational attainment of type k .

The problem is now to maximize (1) subject to (2) and (3). That is, the optimal combination of supplies to the various occupations is derived from the representative agent's maximization of income subject to a Skill Transformation Frontier, where the skew and capacity parameters of this frontier are dependent upon exogenously determined attainments in various educational categories.

- (i) if there is no change in any one attainment category, there is no change in the capacity index (even though there may be changes in the other attainment categories) ;
- (ii) the absolute value of the uniform component of attainment changes cannot be greater than the absolute value of the minimum overall change in any individual category ;
- (iii) if all attainment changes are equal in size, there will be, by definition, no changes in the Q_i 's, and the effect will be transmitted via changes in the capacity index alone .

The importance of property (i) is that it allows for the possibility of the specific input-output relationships of the manpower requirements approach. Taking an extreme example, if there is no change in a particular educational attainment category, then any occupation which is totally specific to this category, will be unaffected. This is most conveniently handled if, in these circumstances, the capacity effect is, by definition, zero.

In summary, changes in educational attainments have a neutral effect on occupational possibilities through changes in the capacity index and a non-neutral effect through changes in the bias parameters. The component of change in attainments which affects capacity is defined to be uniform across all attainment categories, and the bias producing component is the residual discriminatory change in each category. Finally, the uniform change component is measured as the smallest deviation from zero in all changes in the attainment categories.

As discussed in Section 2, the component of changes in educational attainments which affects the capacity index is defined to be a uniform change across all categories. Thus the capacity producing component can be written as :

$$\dot{N}_k^c = \dot{N}^c \quad \forall k \quad (11)$$

so that (9) becomes

$$\dot{L} = \dot{N}^c \sum_{k=1}^m \alpha_k \quad (12)$$

It remains to define the measurement of the uniform change component. Although any definition is to some extent arbitrary, we define the uniform change component as the smallest deviation from zero in the percentage changes in all educational categories. In other words, the uniform change component is equal in sign and magnitude to the percentage change which is smallest in absolute value across all categories. Thus, the uniform change component can be negative, zero, or positive. We write the definition as

$$|\dot{N}^c| = \min\{|\dot{N}_k|\} \quad (13)$$

This definition unlike other alternatives, combines three desirable properties :

1. Possible alternatives to definition (13) are, for example,

$$\dot{N}^c = \text{average } \{\dot{N}_k\}$$

or

$$\dot{N}^c = \text{percentage change in } \left(\sum_{k=1}^m N_k \right)$$

5. THE PROBLEM ILLUSTRATED

We provide here diagrammatic representations of the mechanisms of change in the above system. For two occupations and multiple educational attainment categories, we demonstrate the effects of three mechanisms by which the optimal occupational supplies can change.

(a) Change in Relative Wages

Holding educational attainment constant, and therefore labour capacity and the occupational bias constant, the wage of occupation 2 increases relative to occupation 1. This is represented in Figure 2 as a shift in the relative wage line from RL_1 to RL_2 . The optimal supply from occupation 1 decreases from OX_1 to OX_2 and the supply from occupation 2 increases from OY_1 to OY_2 .

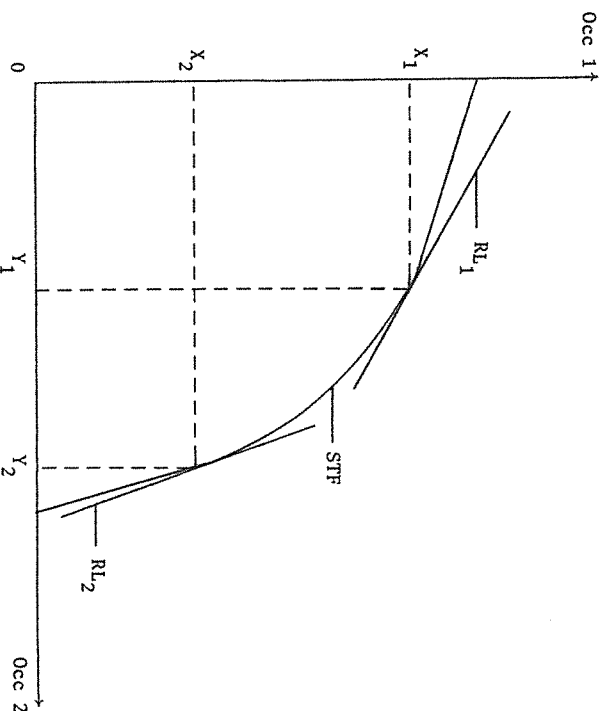


Figure 2 : Effect of a Change in Relative Wages

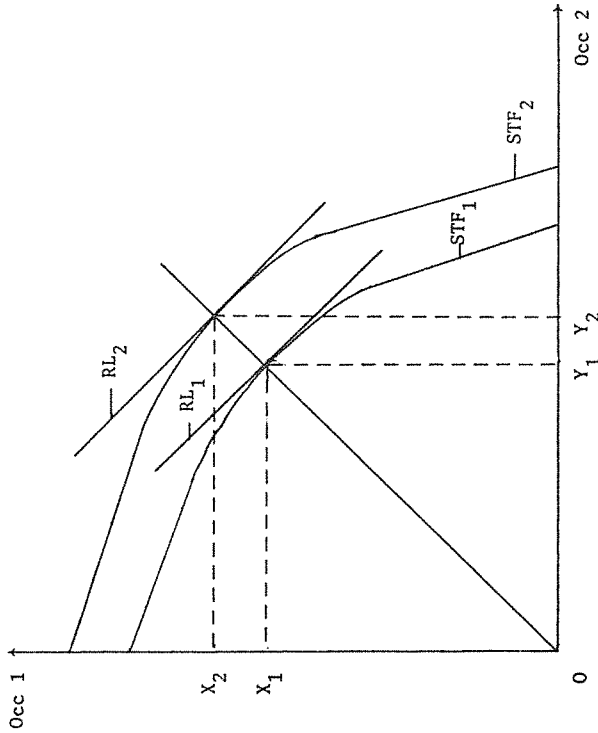


Figure 3 : Effect of an Increase in the Labour Capacity Parameter Due to a Uniform Increase in Attainment Levels.

(b) Change in Labour Capacity

Let us now assume that relative wages remain constant, but all types of educational attainment expand at a uniform rate. This is captured as an increase in labour capacity, or, in terms of Figure 3, as a neutral shift in the STF from STF_1 to STF_2 . The optimal supply of both occupations increases as shown. Note that the STF illustrated is homothetic such that, with shifts in the position of the STF, the ratio of occupational supplies is preserved.

where

\dot{N}_k^c = capacity producing component of the percentage change in educational attainments of type k ,

\dot{N}_k^b = bias producing component of the percentage change in educational attainments of type k .

We specify the relationships between changes in educational attainments and changes in the capacity and bias parameters as :

$$\dot{L} = \sum_{k=1}^m \alpha_k \dot{N}_k^c \tag{9}$$

and

$$\dot{Q}_i = \sum_{k=1}^m \gamma_{ik} \dot{N}_k^b \tag{10}$$

with the prior restrictions,

$$\alpha_k > 0, \tag{9a}$$

$$\gamma_{ik} \leq 0. \tag{10a}$$

In the light of the definitions introduced below these restrictions ensure that the relationship between changes in educational attainment and the capacity and bias effects, in both cases, positive as required.

We have stated that educational attainment can have two types of effect on the set of occupational possibilities - a neutral effect (i.e. equi-proportional changes in occupational supplies) captured by the capacity parameter, L , and a non-neutral effect captured by the bias parameters, Q_i . However, it is not meaningful to consider the specification of the relationships between educational attainments and the capacity and bias parameters in terms of levels, since this would require, in concept, the ability to divide the total stocks of educational attainments into capacity producing and bias producing stocks. Instead we can quite sensibly apportion any change in educational attainments into a capacity producing component and a bias producing component, and specify the relationships in terms of (percentage) changes. We do this in the following way.

Recall that

$$\bar{\theta} = \{L; Q_1, \dots, Q_n; r_1, \dots, r_n\} \quad (7)$$

and

$$\bar{\theta} = f(N_1, N_2, \dots, N_m) \quad (3)$$

In order to specify (3) in terms of percentage changes, we divide the total percentage change into a capacity producing component and a bias producing component. Thus, for educational attainment category, k ,

$$\dot{N}_k = \dot{N}_k^c + \dot{N}_k^b, \quad (8)$$

(c) Change in Occupational Bias of the STF

For given relative wages, a discriminatory change in educational attainments will alter the existing biases in the set of possibilities towards certain occupations. Suppose as a result of some previous decision, changes in attainments in various educational categories alter the suitabilities and preferences of the workforce toward occupation 2 and away from occupation 1. This is reflected in Figure 4 by a shift from STF_1 to STF_2 . In other words, attainments in educational categories with a comparative advantage in producing occupation 2 skills increase, while attainments in those educational categories with advantage in producing occupation 1 skills decrease. As a result of these discriminatory changes in educational attainments there is an increase in supply from occupation 2 and a reduction in supply from occupation 1.

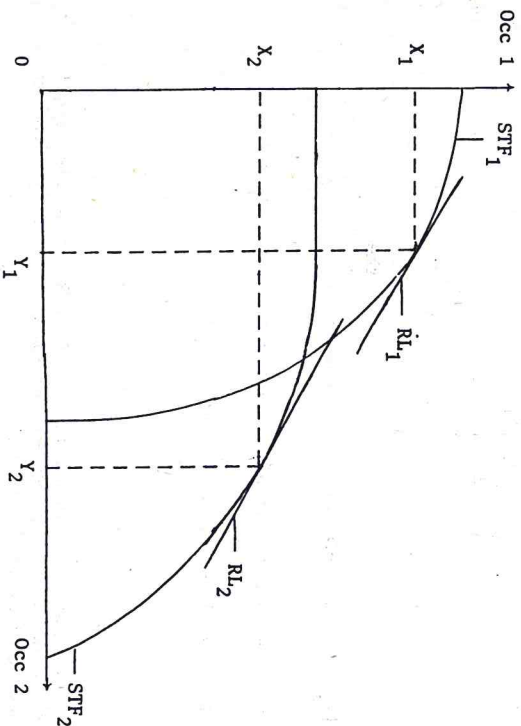


Figure 4 : Effect of Change in Occupational Bias Parameters Due to Non-uniform Changes in Educational Attainments.

The solution can be found by forming the Lagrangian and solving the set of equations from the first order conditions for a maximum (see Appendix A). The resulting supply equations can be written in percentage change form (signified by a dot over the symbol for a variable) as:

$$\dot{L}_i = \tau_i (\dot{W}_i - \sum_{j=1}^n S_j^* \dot{W}_j) + \dot{L} - \dot{Q}_i - \tau_i (\dot{Q}_i - \sum_{j=1}^n S_j^* \dot{Q}_j) \quad (5)$$

where,

$$\tau_i = \frac{1}{r_i - 1}$$

and

$$S_i^* = \frac{\tau_i W_{i1}^L / \sum_{j=1}^n W_{j1}^L}{\sum_{\ell=1}^n (\tau_\ell W_{\ell 1}^L / \sum_{j=1}^n W_{j1}^L)} \quad (6)$$

Although L and the Q_i 's are parameters of the STF, they are allowed to vary over time as functions of educational attainments. The parameter L reflects overall labour capacity and the Q_i parameters determine the bias of the STF. Note that a decrease in Q_i leads to an increase in the bias in the set of occupational possibilities towards occupation i . The transformation parameters, r_i , however, are assumed to be fixed for this analysis.

4. THE PROBLEM SPECIFIED

In this section, we specify functional forms, solve the problem (1), (2) and (3) and suggest further a priori restrictions. We impose the constant returns to scale version of the CRETH¹ specification for the STF, and concentrate attention on the specification of the educational attainment relationships. Other specifications for supply transformation possibilities will be included in the estimation phase.

The problem can now be written as :

$$\max \sum_{i=1}^n W_i L_i \quad (1)$$

subject to

$$\sum_{i=1}^n \frac{Q_i L_i}{L} r_i = 1, \quad (4)$$

where

- { r_i } = n transformation parameters, $r_i > 1$;
- { Q_i } = n distribution or bias parameters, $Q_i \geq 0$;
- L = index of labour capacity.

1. The Constant Ratio of Elasticities of Transformation Homothetic specification is outlined in Hanoch (1975). An application is provided by Dixon et al. (1976).