Section 3. Constrained Optimization in Education Choice

The model used here was first developed by Tan and Danao in 1976 for the PREPF[1/] project. Education is treated as a human capital and conventional investment decision criterion is applied to the choice of pursuing alternative types of education including zero education. Two major constraints are built into the model - financial and informational.

Following Hicks (1973) we consider choice among relevant alternative capital processes rather than of alternative capital stocks, or capital expenditures. Education has a peculiar process of capital build-up. A capital process is a flow of inputs and outputs over a time period. Each process is evaluated by taking its capitalized value, i.e., discounting all input and output flows. No distinction is made between capital and current expenditures. What matters in the valuation of capital is the timing of expenditure and output. A given plant and equipment may be built with different time paths and once built, the flow of inputs and output can still vary. The same physical plant and equipment may involve different capital processes. Using the concept of capital process frees capital choices from the more limited choices of capital goods. It might also rid us of the two-Cambridge capital controversy of what capital is and how it is to be valued.

Assuming a number of proceeses, each process j has a net

[1/] PREPF is Population, Resources, Education in the Philippine Future.

worth computed from its flow of inputs, C_{jt} and outputs, R_{jt} over T periods :

$$NW_j = \sum_{t=0}^{t-1} \frac{R_{jt} - C_{jt}}{(1 + r)^t} , \quad j = 1, 2, \ldots, n \qquad (1)$$

Where r, the rate of interest, is assumed constant over time t = 0, 1, 2,.., T - 1. At some rate of interest and other cost, we obtain a ranking of the processes 1 to n. The ranking order may change with changes in the cost of capital or discount rate so that a process with large capital expenditures and early pay-off or early flow of receipts would become more profitable than one with a longer spread of capital inputs and later output flow at high rates of interest. Once the NW_j's are estimated choice is easily made with the objective of maximizing NW_j. Constraints on choice may be imposed such as capital rationing and mutually exclusive processes. Net worth is to be maximized subject to whatever constraints apply.

a. Application of Capital Theory to Education.

The concept of human capital has been accepted without much question. In just over a decade since Schultz' revival in 1960 of earlier works on education as human capital, works on economics of education have assuned a major bulk of the economics literature. However capital choice theory may be applied to education only at great simplification of education options. Education is not clearly observable. It can be defined more meaningfully in a philosophical sense than as an observable capital variable. As a capital good counted at a point in time, it is a whole range of knowledge acquired by an individual consisting of all scientific, linguistic and artistic information absorbed; the discipline to reason, analyze information, and make correct judgment; and the ability to search for new information and create new knowledge. Special skills used in production of goods and services such as engineering, bookkeeping and surgery have also been included in the definition of education. This multi-faceted nature of education as a capital makes it difficult to categorize and to measure. There is no accurate measure of its many components. For this reason, very rough categorization has been used in planning and empirical works.

The usual classification used is by type of schooling such as the various grade levels, the various fields of specialization in college, and formal or non-formal education, the latter including skills training and informal campaigns. These, it is to be noted, are extremely rough categorization since it does not distinguish levels of actual knowledge. Despite this problem we proceed in the conventional manner.

Most of the schooling types of capital are additions to basic, i.e., primary education capital. Let us take the case of medical education. An investor in this capital would have to acquire elementary, high school, a few years of general education in college before being able to enroll in medicine itself. The capital is acquired in a certain sequence. In fact each type of schooling capital could be considered as the sum of a sequence of schooling, or sequences of investment, i.e., completion of grade 1, grade 2, ... pth year medical college so that medical schooling capital, K^{p}_{mp}, valued at time p can be written as

$$K^{p}_{mp} = \Sigma^{p}_{mp-1} + I_{p} = \sum_{t=1}^{p} I_{t}(1 + r)^{p-t} \qquad (2)$$

since in general

$$K^{t}_{t} = K^{t}_{t-1} + I_{t} \qquad (2')$$

If capital is valued at time zero

$$K^{0}_{mp} = \sum_{t=1}^{p} \frac{I_{t}}{(1 + r)^{t}} \qquad (3)$$

where I_t is investment at time t, $t = 1, 2, \ldots, p$. Time t in education is generally in annual units.

Any change in desired level of schooling capital would be made through a similar sequence of investment. The observable flow of investment is the expenditure in each grade leading to the desired schooling. If the desired number of medical degrees increases at time t everything else constant, investment or enrollment in preparatory schooling for medicine will also increase. Necessarily, there will be a lagged relation between changes in desired schooling capital and its acquisition, the lag depending on the length of the program.

A special feature of the formal schooling process is that there is a fairly rigid annual sequence of capital build-up from kindergarten up to the university level. The curricula for elementary up to sophomore college are usually for general education. Specialization takes place beyond sophomore in college and in sub-professional vocational-technical training. Intensity of specialization in a field increases as one moves from first to second and to third degree programs. The latter is a very important feature of formal schooling as it is provided currently. The heavy content of general education up to first degree programs permits much flexibility in labor adjustment to changes in skill requirements. One can easily move up the sequence or change fields of specialization while still in school or after joining the labor force. All these changes can be accomplished in a fairly short time. A shift of specialization in college will take less than four years and may be completed in just one year for related fields. A shift in graduate degree fields may take as much as the full length of a graduate program. Pursuit of medical or a Ph.D. degree takes about four additional years from a first degree. Nevertheless these are short gestation periods relative to worklife, or the lifetime.

Because of the sequential nature of formal schooling investment, an important benefit of attaining a certain level of schooling is the value of being able to pursue succeeding levels. A high school education is very valuable in this sense as it allows one to pursue a number of post-secondary education. In contrast an elementary education permits one to go on only to the next higher level of general education. Another feature of this capital is that it cannot be destroyed except by obsolescence or depreciation resulting from its idleness. Memory dims with time elapsed since last perception or learning of an object, a fact or a theory. On the other hand, one can build on a given stock of knowledge after leaving school. The ability to learn is itself an output of education.

Men are born with differing innate characteristics. There is unequal distribution of mathematical, artistic, linguistic, and even physical abilities. The varying historical and cultural backgrounds of families develop dissimilar values and attitudes. There is a distribution of these characteristics among the population of a nation though there may be common relative strength in any one or in a few characteristics viz other nationalities. The cost to an individial, psychic as well as monetary of acquiring a certain category of education, depends on his innate characteristics given school-related cost. Let us call this personal cost. Personal cost varies depending on the degree of matching of innate characteristics and those suited or required by the education category pursued. A mismatch will require of the student longer and more intensive input in his studies to overcome his poor ability in the subject. It might also mean psychic cost in the form of smaller satisfaction from the education pursued. The personal cost of pursuing a Ph.D. degree in Physics may be prohibitive for someone who has very poor innate ability in this field and who enjoys and is inclined to music or the stage.

Because of differences in innate abilities, attitudes and values, an individual will not be indifferent to education options that give equal monetary returns. Or an increase in the relative monetary returns to an option would not attract everybody to undertake that education process. We would expect instead an upward sloping enrollment of students in a given option. Monetary return has to compensate the personal cost of undertaking an education process in which students have weak abilities and inappropriate attitude. At some point the supply may turn vertical as personal cost becomes prohibitive because of utter lack of talent and dislike for the education of the marginal population. For this reason the supply elasticity is expected to decrease with intensity of specialization and for fields that require special abilities like the arts. There are many areas of education where supply is fairly elastic. Everyone qualifies for the lowest education levels. In fact many countries have compulsory elementary or even high school enrollment for children of the corresponding schooling ages starting from age six or seven years old. Most first degree college programs containing many courses of general interest should also have fairly elastic supply. First degree graduates of teacher education, business, psychology, liberal arts and even engineering have been more prone to shifting occupations from those which correspond to their majors.

Monetary cost of providing education varies by level and by field of specialization. In general cost increases with level. Higher levels seem to have larger scale economies. These have lead to the establishment of relatively large colleges and universities and their location in population centers. Some fields require more capital stock per pupil. Quality of instruction also depends on level of expenditures for teachers, laboratory and library.

The monetary cost to the student includes cost of instruction charged to him, foregone income and marginal living expenses including transportation in going to school. Geographic access to schools differs among students. There is a concentration of colleges and universities in large cities while primary schools are provided in all towns and large villages. High schools are not yet universally accesssible though many larger towns have them. The degree of dispersal of schools determines the distribution of distance among population groups. In most cases provincial students must bear a higher schooling cost than city students because of distance of their homes to schools. For this reason cost of distance tends to be higher the higher the level.

The distribution of schools among geographic areas and the distribution of ability and aptitudes are basic factors determining the supply function of students in each educational program. The more specialized it is, the steeper the supply curve. The derivation of the supply curve is discussed below using the above constrained optimization model. Psychic and distance costs have to be included in the cost parameter used in the optimization problem.

b. Constrained Optimization Model and the Supply of Graduates

In the model we assume families to be maximizing the networth of their children' education subject to two constraints, cost and ability. (Net worth is used equivalently with returns to education.)

$$\text{Max } NW_j^i = \sum_{t=1}^{j} \frac{R_t^{ij} - C_t^{ij}}{(1+r)^t} - \sum_{t=1}^{e} \frac{R_t^{i,e} - C_t^{i,e}}{(1+r)^t} \qquad (4)$$

st.

$$C_t^{ij} \leq B_t^i \ , \quad C_t^{ie} \leq B_t^i$$

for each year of schooling t = 1, 2 ... j corresponding to age 7, 8 ... j + 6. For those desiring college

$$A^i \geq \bar{A}^j \ , \quad A^i \geq \bar{A}^e$$

where R is expected benefit, C is total cost for each year t in pursuit of education , j, of child i. The budget B_t for each child of corresponding age a is a function of family income, Y_f.

$$B_t^i \equiv B_a^i = b_a (Y_f^i) \tag{5}$$

$\bar{A}$ is the minimum ability required for education e, j. Ability A is found to be strongly influenced by family income also. These constraints determine the set of alternatives which are relevant to children of given backgrounds and abilities.

Consider a population of children of a certain age range with its distribution by family income, distance to school facilities and abilities. Array the children by their schooling cost and map this distribution to the budgets for schooling. Children of age a can go to school so long as $C_a \leq B_a$. From this mapping we identify the children who can and those who cannot pursue each education alternative corresponding to their age a. The whole set of alternatives over all schooling ages of a child may also be obtained for given values of expected family income. We find that a given distribution of income, distance to school and abilities generate a distribution of sets of alternatives. The richer and brighter a child is, the larger the set facing him. The poor bright child in a distant location may face a set that is not significantly larger than that of his dull counterpart. On the other hand, superior quality of school and home environment in which rich children are brought up can so offset inferior inherent ability as to break the ability constraint for their higher education.

Market adjustment to relative rates of return to education will be made within the defined sets of relevant alternatives. A decreasing proportion of the population is expected to respond to positive returns to higher education, in particular, the more costly college programs. For this reason, disequilibrium in rates of return between costly and inexpensive program may be expected to persist or to be stable. In fact, this stable disequilibrium situation is frequently observed in many LDCs including Thailand and the Philippines.

Consider the following supply curves of graduates of different programs, A, B, C, which have increasing ability requirements. Gross return of A is in relation to B, that of B in relation to C. More specifically,

$$GR_B = \sum_{t=1}^{B} \frac{R_{Bt} - C_{Bt}}{(1 + r)^t} - \sum_{t=1}^{A} \frac{R_{At} - C_{At}}{(1 + r)^t} \quad \text{and}$$

$$GR_C = \sum_{t=1}^{C} \frac{R_{Ct} - C_{Ct}}{(1 + r)^t} - \sum_{t=1}^{B} \frac{R_{Bt} - C_{Bt}}{(1 + r)^t}$$

R_t is expected monetary benefits and C_t is cost of tuition, books and supplies at time t, excluding pesonal cost.

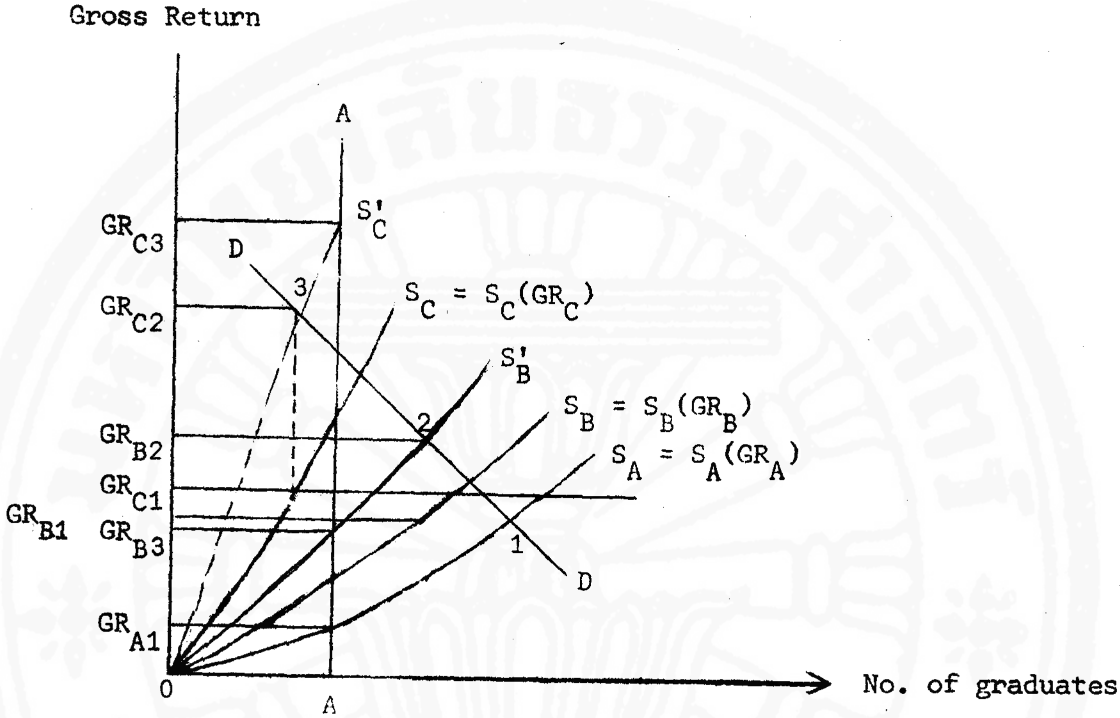

Chart 1

The S curves are the supply curves that would make marginal net returns (net of personal and distance cost) zero. As ability increases, the supply curve becomes less elastic. Differential in gross return must cover increasing personal cost of pursuing more stringent programs. Financial constraints should make the more costly higher education C programs even less elastic than if these were absent. This constraint is reflected in shifts to S'_C and S'_B. It is seen that a positive return to C over B education attracts less students than the same return to B relative to A. Take a demand curve DD. Operating at the S' curves would result in a disequilibrium in the market. Those able to meet the financial constraint for C will be earning positive net returns, say $GR_{C2} - GR_{C1}$ for C program and $GR_{B2} - GR_{B1}$ for B program.

The chart also shows that at a given level of gross return, the supply is smaller the higher or more specialized the education. A substantial gross return differential as indicated by the intersection of the vertical supply line AA and the respective S' curves is needed in order for there to be an equal number of graduates pursuing each program. The return differentials required for equal response of students are $GR_{C3} - GR_{B3}$ and $GR_{B3} - GR_{A1}$. The quantity supplied in each program is not positively related to the relative gross return. Moreover, an upward sloping aggregate supply cannot be meaningfully drawn.

We underscore the implications of the budget constraints on decision and test a hypothesis of determination of school attendance based mainly on this constraint. Irrespective of what may be the relative gross returns to schooling of different levels but provided they are not negative for the higher levels, we may argue that school attendance at each level will be mainly a function of variables affecting the financial constraint: family income, distance to school and level and type of program. As earlier explained, the longer the distance to school the larger are transport and additional living expenses.

Tuition, other fees and other expenses, in general, increase with level. Distance also increases with level since there are fewer higher educational institutions most of which are located in central cities. The financial constraint thus becomes more stringent with level of schooling.

Other variables that might influence family decision are father's education and number of sibling. There is a tendency for families to preserve its socio-economic position so that children are directed to the education and occupation that are at least as prestigious as the father's.

Given the above reasoning we argue that the probability of a child of a given age to attend a schooling level corresponding to this age is taken to be a function of all the above mentioned explanatory variables. And since the process of education is sequential, we assume a conditional probability function as follows:

$$P^{j}_{ia} = P^{j}_{a}(Y_{fi}, E_{fi}, L_{fi}, N_{i})P^{j-1}_{ia-1} \qquad (6)$$

$$P^{j-1}_{ia-1} = P^{j}_{a-1}(Y_{fi}, E_{fi}, L_{fi}, N_{i})P^{j-2}_{ia-2}$$

If a child did not complete the preceeding level, the probability of his attending the next level is zero. The probability of his pursuing other succeedingly higher levels is also zero at a given point in time. The family may decide to let him complete the previous level at a later time. This allows him subsequently to pursue next levels.