1969

A model determining optimal paths for individual investments in education with application to metal workers

James Jay Mikesell
Iowa State University

70-13,612

MIKESELL, James Jay, 1942-
A MODEL DETERMINING OPTIMAL PATHS FOR INDIVIDUAL INVESTMENTS IN EDUCATION, WITH APPLICATION TO METAL WORKERS.

Iowa State University, Ph.D., 1969
Economics, general

University Microfilms, Inc., Ann Arbor, Michigan

A MODEL DETERMINING OPTIMAL PATHS FOR INDIVIDUAL INVESTMENTS IN EDUCATION, WITH APPLICATION TO METAL WORKERS

by

James Jay Mikesell

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State University
Ames, Iowa

1969

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

I. INTRODUCTION

A. The Problem

The problem attacked in this study is development of a comprehensive model to describe the decision process of a person planning his lifetime path of educational training, leading to eventual employment. When one views the multitude of possible occupations and applies the limited knowledge possessed, he faces a difficult choice-making decision.

Information one holds about entry requirements, payoffs, availabilities, and the nature of the job market faced may be inaccurate, sketchy, or incomplete. Thus, one aspect of the individual's problem might arise from lack of reliable information. However, an individual with perfect information may lack a logical tool for comparing the alternatives. Further, it is quite possible that a person would reach a suboptimum solution to his job choice problem with a chance selection from the set of alternatives. Since the decision criteria of a rational man can be specified in broad enough terms to fit a situation faced by any particular individual, regardless of lack of knowledge, existence of risk, or attitude toward risk aversion; developing a comprehensive job and training choice model seems possible.

Relationships between human capital theory and what might be referred to as "traditional" capital and investment theory, which deals with physical capital, have not been clearly specified. Adaptation of traditional capital and investment theory to human capital can give insights relevant to decisions on how much to invest in human capital and what directions such investments should take.

The appropriate use of capital and investment theory, when dealing with educational investments in human beings, is only a continuation of earlier developments in economics of education and human capital theory. The concepts of present-value and internal rates of return have been widely used in analysis of educational investments. Up to date analyses telling when the use of each of these concepts is appropriate and when their use is not appropriate (as have been developed in traditional capital and investment theory) need also to be developed for human capital and investment theory. An analyst or decision-maker needs to know limitations and strengths of concepts. When a tool is used, it should be done with full realization of the technique's limitations. Limitations on economic tools are the restrictions created by the assumptions underlying the technique. These tools make use of deductive logic, going from assumptions to logical conclusions. The reliability of such economic tools for problem solving depends ultimately on the reality and validity of their assumptions, having satisfied oneself that their logical development is correct. The assumption of a single, identifiable, interest rate makes applications of the present-value concept and internal rate of return concept (8, p. 37), to investment value or worth usually equivalent and always appropriate in the treatment of educational investments. It will be shown that it is not necessary to make such an assumption and that the proper discount rate is related to the person undertaking the investment. Making use of this more realistic assumption about interest rates (thus making the assumed world more closely resemble the real world) should be expected to yield results that could be more confidently applied to the real world.

Basic to the idea of modern economics is the principle of maximization of benefits, using marginal analysis. Within the concept of maximization by marginal investments, some economics of education studies try to identify optimum allocation of resources between education and all other possible resource use, and among alternative types of educational investment. In all situations the concept of maximizing the return on the marginal investment is the guideline.

Analysts working in the area of economics of education find abstractions from the real world to be necessary in conceptualization of ideas and in application of analytical tools. These economic abstractions, or models, common in economics, are structured in economics of education for the same analytic purposes. Not only do these abstractions take the form of simplification of ideas but, in a very similar vein, they eliminate from consideration many characteristics of the total universe (only those which are irrelevant, hopefully).

The economist might be viewed as facing a universe of independent and dependent variables. The independent variables are those things which can be manipulated directly or are expected to bear a causal relationship to the dependent variables. The economist selects the item, or weighted group of items, which he wishes to maximize. The remaining steps in the economist's procedure are to abstract from all items which may affect the dependent variable only those which he suspects are independent variables. These are tested to find which independent variables are important, and exactly what their effect is on the dependent variable.

It is found, then, that general equilibrium analysis in economics is too broad in concept and in magnitude to reflect accurately meaningful relationships in economics of education. Partial equilibrium analysis is used generally for this kind of research. In this way the detail necessary for meaningful analysis can be obtained, and most importantly, interrelationships still identified.

In the economics of education field such partial equilibrium analyses are used for both micro-economic and macro-economic problems.

While economics of education is definitionally restricted to the role of education within the economic world its total scope is actually quite broad. It encompasses both micro-economics and macro-economics through the differential approaches to educational costs and benefits from individual, firm, and national viewpoints.

Among the major areas of traditional micro-economic theory given wide usage in the economics of education field are consumption theory, theory of the firm, and growth theory.

In the macro-economic area the problems of a country or of some other geographic area are treated by trying to discover the interrelationships between educational investments and other segments, or characteristics, of the society. One of the most popular applications of this type of study is in growth theory and in the effectiveness in speeding economic growth, particularly in underdeveloped countries. It is the usual case in underdeveloped countries that education, as embodied in human capital, is relatively scarce and its productivity is relatively high.

The study of the economic nature of education has been criticized because it treats only a portion of what is a much more complicated matter. Robert G. Spiegelman has presented three reasons for studying the economic objectives (78, p. 1); they are important, they are susceptible to quantifiable measurement, and recent studies show that education can contribute to national product.[1]

Becker was one of the first to subject education to micro-economic theory. He showed that methods of micro-economic theory can be applied to explanation of individual investments in education. Within this framework Becker fostered a somewhat broader concept of education than usual. He saw investments in people taking such forms as on-the-job training and medical care, as well as formal education. This study will deal with the manner in which an individual invests in formal and vocational education to achieve an optimal mix of skills (i.e. human capital).

B. Divergence of Private and Social Optimums

The economist is constantly faced with situations where the maximizing efforts of individuals, when viewed in aggregate, do not result in a maximizing situation for society. The complicating factors which

---

[1]Spiegelman has cited five studies supporting this statement. These studies indicate that "advance of knowledge" accounted for two-fifths of the growth in real income in the U.S. from 1929 to 1957 (26). They show that, 1) people receiving more education tend to earn more, even after adjustments for differences in sex, region, race, ability, physical condition and other items; and 2) the combination of general and vocational education tends to pay off more than only vocational education (78, pp. 1-3).

cause this divergence can be covered in the single category of factors which cause social costs to differ from an individual's costs, and factors which cause social returns to differ from an individual's returns. These costs and returns both refer to these elements for decisions of a single individual. The fact that particular costs and/or benefits differ does not, however, insure that the actions of individuals will not result in the optimum for society. Compensating distortions may occur with the resulting situation being a social optimum.

While some distortions are characteristic of the system, such as externalities and the social versus the individual discount rate, other distortions, such as the public versus the individual cost of education, can be manipulated (if only very slowly and within narrow bounds) and may be used by society to make the aggregate of individual decisions conform more closely to what is deemed as socially optimum.

An important cause of the divergence in social and individual optima is the externality. This may take the form of either an external economy or an external diseconomy. In the case of education these externalities are most often considered to be economies, resulting from such items as economic growth which is stimulated by the educated, or from a more responsible government. The first type of externality, which leads to greater economic prosperity for everyone, is the principal externality attributed to education. As such this is a principal justification for the large expenditure of public funds to subsidize the educational system.

That optima may differ for individuals and for society is one of the two major reasons for educational subsidies. The other major reason is for income redistribution, both immediate subsidies to students and capital investments in people of many financial backgrounds. These capital investments lead to increased future income and possibly a more even distribution of income in the future.

One of the principal objectives of this study is to discover if a divergence of individual and social optima is likely to occur in the choice of occupations. If there are divergences, it is important to consider how great these divergences are and what factors are most important in causing these divergences.

C. Cost-Benefit Analysis - A Maximization Technique

The cost-benefit analysis is used to place measures on alternative programs and, thus, give a rational basis for choice among them. While some studies may relate the average aggregate returns to education, policy decisions are made on the basis of the specific contributions expected from individual programs. This maximizes the return from a marginal educational investment. When costs include the returns forgone the objective of economic policy should be to maximize the discounted difference between benefits and costs. Cost-benefit analysis is the method by which benefits and costs are valued and these values then discounted to present-values.

A present-value of an asset is the sum resulting from discounting a stream of net returns from that asset, to the present, and summing these discounted returns. In calculating present discounted costs and benefits the cost-benefit analysis essentially calculates two present-values. The present-value of costs is subtracted from the present-value of benefits to obtain an estimate of the net benefit.

Alternatively, costs could be treated as negative benefits and only one calculation made for the present-value of the particular investment. Actually the use of cost-benefit and present-value are equivalent. The difference in these methods is that present-value is generally applied to individual capital investments while the cost-benefit analysis is applied to entire projects to justify their use, or to choose between several of them.

Using the cost-benefit approach, a simple formula for educational benefits would be:

$$B_W = \sum_{i=1}^{n} N_i \sum_{j=1}^{T_i} (1 - r_{ij})^{j-1} W_j/(1-d)^{j-1} , \quad \text{where} \tag{1.1}$$

B_W = discounted benefits from increased wages

i = the age group of the n different groups

N_i = the number of people in age group i, in the program

j = the year, from the present (1) to retirement (T_i)

T_i = the number of years until retirement for age group i

r_{ij} = the probability that employment will be terminated because of death or disability in year j, for age group i

W_i = the net increase in yearly wages, due to the program, in year j

d = yearly discount rate for future earnings.

In the preceding formula all discounted benefits are realized from an increase in wages. If other factors are to be considered as benefits accruing to the individual their values should be added to the W_j term, and the resulting net value, R_j, substituted for W_j. There may also be benefits to society, not accruing directly to any of the individuals considered explicitly. Such benefits need to be treated separately from the individual returns. A new formula for total discounted benefits can then be represented by:

$$B_T = \sum_{i=1}^{n} N_i \sum_{j=1}^{T_i} (1-r_{ij})R_j/(1-d)^{j-1} + \sum_{k=1}^{T_i} S_k/(1-d)^{k-1}, \quad \text{where} \qquad (1.2)$$

B_T = total discounted benefits

R_j = the net increase in individual benefits, due to the program, in year j

k = the year, from the present (1) to the time horizon (T)

S_k = the net increase in social benefits (not accruing to individuals in the program) in year k.

While the costs are often realized in a lump sum, at the beginning of the time period, they may also be strung out over several time periods. In this case costs must be discounted in the same manner as returns. Costs can also be divided into private costs to participants and social costs. Private costs consist of direct costs, such as books and tuition, and income forgone. Social costs are the total costs of the program, net of tuition payments. A formula for discounted costs is

$$C_T = N \sum_{j=1}^{T} C_j/(1-d)^{j-1} + \sum_{j=1}^{T} C_{sj}/(1-d)^{j-1}, \quad \text{where} \qquad (1.3)$$

C_T = total cost

$$N = \sum_{i=1}^{n} N_i$$

j = the year in the program from the present (1) to completion (T)

T = the number of years until completion of program

C_j = private cost per individual in the program, including direct costs and income forgone

C_{sj} = social cost of the program, net of tuition payments.

Cost-benefit analysis is subject to numerous shortcomings and possible pitfalls which include, the failure of the market mechanism to achieve an efficient allocation of resources, the existence and the estimation of external diseconomies, the estimation of future values, the identification of the proper discount rate, the identification and the valuation of alternative uses of the resources (if this is considered), and the general impossibility of including all possible items of cost and benefit. In elaboration of the last of these shortcomings, there are numerous nonquantifiable items which, by this characteristic, cannot be explicitly included in the cost-benefit analysis, but which are still quite important. Gerald G. Somers considers this nature of cost-benefit analysis in evaluating social welfare programs in his statement that, "moral, social and political considerations may very well be more important, and those who engage in cost-benefit analyses are not--or should not be--unmindful of this fact" (77, p. 4).

Recognizing these limitations of cost-benefit analysis it can be supposed that a cost-benefit analysis of an educational program is likely to be an inexact partial analysis. Indeed, the cost-benefit analysis is such a procedure of educated guesswork. At the same time few would deny that it does indeed add a needed element of light to the procedure of choosing between alternative programs. There is also a certain redeeming quality in the same inexact nature of cost-benefit analysis that brings much of the criticism against it. While the analysis is limited to dealing with certain quantifiable parameters the selection of what parameters to consider and how they are to be valued allows a weighting of elements, according to their social importance.[1]

A major difference in the cost-benefit studies which have been done in education lies in the items considered as costs and as benefits. Benefits may include the reduction in juvenile delinquency, as for Spiegelman (78, pp. 109-119), or be only the net increase in expected earnings, such as Becker uses (8). In the calculations of educational costs it is not clear which items should be included. Cost estimates may be the average total cost per student or some lesser amount, such as average total cost minus capital expenditures, or average instructional cost. While these are reflections of societal costs individual costs might also be used. These costs are the sum of tuition, income forgone, educational supplies, and any other expenditures which are specific to the particular educational program, such as transportation to and from classes. The proper items to include in the calculation of either costs or benefits depends on the problem to which the results are to be applied.

D. Present-Value and Rate of Return-Maximizers

The present-value theorem equates the current value of an investment to the stream of net revenue available from it, discounted at the

[1]Suppose the major social consideration is the effect of a program upon the incomes of families which have low incomes at present. The social returns considered in cost-benefit calculations may be the increases in individual incomes of low income families and increases in local property values, but not possible change in incomes of higher income families who may face lower incomes because of increased competition for their jobs. Thus incomes of higher income families are implicitly given a weight of zero.

market rate of interest (14, p.483). Under the present-value theorem if the immediate cost of the investment is less than this current value it is desirable to undertake the investment. This difference between current value and present cost is known as the present-value of an asset. The present-values referred to when dealing with this study in economics of education are the present-values of particular income streams. Under the present-value theorem all investments with positive present-values will yield a profit if undertaken. If a number of investment opportunities were available but only one could be chosen, as for an individual choosing an occupation, the optimum selection would be that selection with the maximum present-value.

A decision criterion which is often equivalent to the present-value method is the rate of return. In this procedure the rate of return is the discount rate which would make the discounted stream of net revenue, from an asset, equal to its cost. In the case of a firm, if the rate of return on an investment is greater than the interest rate for funds the investment is profitable. In the case of a firm, with unlimited resources, all such investments should then be undertaken. A different sort of situation faces a decision maker who can select only one investment at a time, such as an individual selecting an educational investment.

Lee Hansen suggests that there are three ways to approach economic returns to individuals from schooling. These are "(1) the value of lifetime earning as set forth by Miller (53), (2) the present-value of lifetime income as set forth by Houthakker (37), and (3) the rate of return on investment in schooling...." (33, p. 137). The studies of Miller and Houthakker, as pointed out by Hansen, do not account for the educational costs and treat the returns as "gravy". Also, the value of lifetime income completely ignores the distribution of income over time, by having no discount factor. These limitations can be overcome by using the present-value approach of Houthakker, but adding negative returns for educational costs. Then it is no longer clear that Hansen's rate of return approach has any advantage over the present-value approach as he stated. It will be shown that, in some situations, the use of the present-value approach is preferred.

Becker (9) and Hansen (33) used very similar applications of the rate of return concept to education. They both dealt with a single general education activity, differentiated only by the level one had reached within the activity. There was only one alternative allowed to staying in the educational activity. This alternative was to enter the labor force, into an occupation defined completely by the educational level of the entrant. As the alternative activity is uniquely defined the income forgone by continuing in the educational program is also uniquely defined. This income forgone is used as one of the costs of the education activity. Except for the possibility of nonunique values,[1] the rate of

---

[1]A problem with the rate of return maximizing procedure is that it does not necessarily yield a unique interest rate, for the rate of return. As an example of how multiple solutions may occur for the rate of return, the following simplified case offers an illustration. In this case, returns are realized only at the ends of two equal length periods and the cost occurs in a lump sum at the beginning of the first period.

$C = R_1/(1+r) + R_2/(1+r)^2$; $(1+r)^2C = (1+r)R_1+R_2$; $C+2rC+r^2C=R_1+rR_1+R_2$

$(C-R_1-R_2)+(2C-R_1)r + Cr^2=0$; Let: $\gamma = C-R_1-R_2$, and $\rho = 2C-R_1$. Then:

$r = (-\rho+\sqrt{\rho^2-4\gamma C})/2C$, or $r = (-\rho-\sqrt{\rho^2-4\gamma C})/2C$.

In this very simple case it is seen that r, rate of return, may have two possible values, with no assurance that they are both real numbers.

return concept is quite accurately used in these analyses of returns from education. This results from there existing only two possible activities, education and work, so that the education activity could be assigned the cost of income forgone by not being in the work activity.

In the case where many educational investment opportunities are available at a given time, but only one can be chosen, the investment with the maximum rate of return is not necessarily that which gives the maximum excess of returns over costs. Such a situation could occur only when the cost and one or more of the returns for the investment with the higher rate of return are smaller than their counterparts for an investment with the smaller rate of return. In such a case, while the rate of return is higher on the smaller investment the "profit", or excess of discounted returns over costs, is greater for the larger investment.

R. S. Eckaus (27) has criticized the rate of return criterion for education and suggested an alternative approach. The basis of this method was to measure these educational requirements directly. He compiled this information on present educational requirements by the following information: "1) a complete listing of employment, sector by sector, in job categories which permit the distinction of the differential educational and training requirements for each sector; and 2) a description for each job category of the amounts of the various types of education which are required for an average level of performance on the job" (27, p. 183). These estimates of educational requirements are the amounts required by the labor force for productive endeavors and, thus exclude unemployed education, education for consumption purposes only, and education used in searching and selection functions.

A critical difference between Eckaus' study and the analysis of this study is that, in the Eckaus study, jobs are broken down by Standard Industrial Classifications (SIC's) and in this study by occupational classifications (DOT's), from the Dictionary of Occupational Titles, 1965 (89). SIC classifications define industries, by their products, and DOT classifications define jobs by their characteristics. Thus, while the industries defined by SIC may have different characteristic job mixes, they aggregate a large number of different job types, requiring different skills, into the same category. Also, the same type of job may well be included in numerous industries. Thus, while aggregate measures of vocational training and general education required are equally valid in both disaggregations the DOT, or a similar type of breakdown, by job types, gives the most meaningful information about what mixtures of the two training types are required. Since each industry includes numerous job types it might be expected that the estimated educational requirements would be more similar between industries than they are between job types.

E. Human Capital

Becker (8) took an integrated approach to individual investments in education and applied the concept of present-value (long a foundation stone of traditional capital theory) to educational investments in humans leading to human capital formation. By discounting both costs and returns by a predetermined discount rate he arrived at present-values for leaving the formal education system at various points. As previously indicated the internal rate of return was also used by Becker to compare the productivity of investments in human education to the productivity of the same resources when invested in alternative manners. Becker's empirical work dealt principally with formal education rather than vocational education. He formulated a general analysis of investment in human capital which offered a unified explanation of numerous empirical phenomena.[1]

The present concern with investments in human capital has developed recently as it has become increasingly evident that the increases in output could not be adequately explained by investments in physical capital

---

[1] "Among these phenomena are the following: (1) Earnings typically increase with age at a decreasing rate. Both the rate of increase and the rate of retardation tend to be positively related to the level of skill. (2) Unemployment rates tend to be inversely related to the level of skill. (3) Firms in underdeveloped countries appear to be more "paternalistic" toward employees than those in developed countries. (4) Younger persons change jobs more frequently and receive more schooling and on-the-job training than older persons do. (5) The distribution of earnings is positively skewed, especially among professional and other skilled workers. (6) Abler persons receive more education and other kinds of training than others. (7) The division of labor is limited by the extent of the market. (8) The typical investor in human capital is more impetuous and thus more likely to err than is the typical investor in tangible capital" (8, pp. 7-8).

alone. Investment in human capital is an important determinant of output as it deals with the changing character of the labor force and, less directly, with changing technology.

At one time economists considered labor as a homogeneous commodity which remained constant over time. Such an assumption is no longer tenable because of a rapid increase in labor skills. Most of the present works in economics of education are in the realm of macro-economics, with some work of a more aggregative nature than others. As investments in human capital are an important determinant of productivity, there is a considerable literature of human capital as applied to growth theory. Other work produced in economics of education, while of a more narrow focus than growth theory and national planning applications, has dealt with returns to formal education. These works treat aggregate data to determine aggregate returns to educational investments. While the models presented by Becker are applicable to the micro problems of returns to the individual, his empirical work deals with the calculation of returns to formal education. While some studies have differentiated the population by factors, such as intelligence quotient (8, pp. 79-88), to derive returns for different groups of the population, they still are far from individual decision models. They do, of course, add some additional information to that already held by individual planners.

The human capital concept encompasses a much wider arena than the singular effect of formal education on human productivity. The educational component of investment in human capital takes the forms of both formal and informal education. The informal component consists of on-the-job training and any other educational procedures of even looser structure. In addition to the educational component investment in human capital also takes the form of investments in health, information about employment opportunities, and investments in migration.

The human capital concept can take one of three different focuses as determined by its basic frame of reference. The first possibility is the totally macro view of the labor force as one productive factor. In such a case methods of investing in human capital may not be differentiated and all become comparable under a common measure of money value of the increase in output. In the aggregate production function such investments may be reflected either as increases in the quantity of labor (i.e. embodied capital), or as changes in the parameters of the production function (i.e. disembodied capital). Another possible frame of reference is the individual, where each individual is treated as a capital unit. In this embodied capital concept the person can be a capital unit of variable magnitude. This magnitude is dependent on the amount of investment which has been embodied in him. There are, of course, numerous levels of disaggregation between the two types of focus presented so far. Breakdowns by geographical determinants, industries, trades, skill categories, educational background, or some other classification may be useful, depending on their application.

The third frame of reference for human capital is also the most disaggregated. In this framework individuals are complex embodiments of many capital forms. An individual is much like a single product firm.

The single product of the individual is his productivity, most likely measured in monetary units. Within his firm the individual wishes to invest in those items which will lead to the maximum excess of returns over costs. Whenever an investment opportunity that yields a rate of return higher than that on alternative investment opportunities presents itself, the individual is motivated to invest in it. Thus, the different skills of the individual investor are analogous to the many types of capital goods of an actual firm. Within this context "traditional" capital theory can be applied to human capital. Some modifications are necessary in the traditional theory as the situations faced by the individual and the firm, while showing the noted similarities, also have several differences. A capital asset acquired by a firm has an expected life which is a function of the investment. A capital asset embodied in an individual has the life time corresponding to the time until the individual's retirement, disability, or death, whichever occurs first. Capital assets of a firm have a value for which they can be sold on the market. The embodied nature of human capital makes it impossible to transfer. A firm can acquire capital in a very short time and can undertake an almost unlimited number of acquisitions at any given time. The process of embodying capital in humans is a time consuming procedure, particularly for informational capital, such as education. This means that humans can select only a limited number of investments at a time. The time consuming nature of educational investments also means that the remaining time of the individual in the job market is reduced by this amount. Since the value of the elements of human capital is dependent on the length of time they are used the existence of many profitable investment opportunities does not mean that all such investments should be made.

The use of a unit of physical capital tends to wear it out and thus decrease both its marginal and total remaining productivities. The use of an element of human capital is likely to increase its marginal productivity; however, its total remaining productivity is still decreasing as total expected productivity anticipates this increase.

When a firm acquires additional units of capital it is generally assumed that the output of these additional units will not affect the output generated by capital units previously owned. (The inclusion of certain economies, or diseconomies, may sometimes be appropriate.) A human is a firm of very restricted scale. The existence of several types of human capital in an individual does not mean that his output is approximately the same as these types of capital would yield if incorporated in several different people. That a person holds the skills needed of a gardener, an engineer, and an economist does not mean that he can perform all three tasks as if he were three different people with each performing one of these tasks. The human firm is thus much like a firm with one critical factor fixed. The analogy might be made to a firm with a fixed quantity of labor, where the use of new capital can be made only at the expense of output from old capital.

In general the firm selects that mix of capital inputs which maximizes its profits, with time required for acquisition a fairly unimportant consideration. The investor in human capital chooses that time path of investments which maximizes the present-value of his flow of output. To him the time required for acquisition of this capital, as well as the time in his productive life at which he acquires this capital, is quite important.

II. INDIVIDUAL EDUCATIONAL INVESTMENTS

A. Theoretical Construct

Human capital and investment in the same, through education, is characterized by the fact that, unlike nonhuman capital, there is a bound beyond which its use in generating future income (Y_1) cannot be substituted for the generation of present income (Y_0). This results from the existence of some maximum rate of use of a human being. That is, there is an upper bound to the output of the human factory. The activities of a human being in a given period affect returns in the future, primarily as nonuse in generating present income is compensated for by additions to human capital, leading to increases in future income. Age, by itself, is assumed to have no effect on income. When the nonuse of human resources in a period is not compensated for by additional investments in human capital (i.e. the individual is unemployed) there may even be some negative effect on future income as nonuse of skills may result in their decrease, relative to the situation existing if these skills were employed in the same period. This possibility realizes that most working experiences are also partially educational experiences. Preliminary constructs are developed under the assumption that there are no original holdings of wealth. The analysis is based on articles by Hirshleifer (36) and Bailey (6), dealing with investment decisions with greatest emphasis on the two-period analysis of Hirshleifer.

Figure 2.1 presents a production possibility frontier,[1] OPO', where the individual has the possibility of being anywhere on, or to the left of and below, the frontier. The figure represents two time periods of equal length with Y_0, the horizontal axis, showing income in the initial period, and Y_1, the vertical axis, showing income in the second, or final period. Obviously all points to the left of and below OPO' are dominated by at least one point on the OPO' frontier. Thus a rational individual would wish to be somewhere on the frontier. This representation of a decision unit operating with limited resources, shows the limiting situations of 1) realizing the maximum possible in the initial period, leaving nothing for the second period, which is point O'; or investing everything in the initial period and reaping the maximum possible return in the second period, which is point O. Intermediate points between O and O' represent the possibility of investing various amounts in the initial period with these investments resulting in increased productivity in the second period. The concavity from below of OPO' reflects the diminishing marginal productivity of additional investments.

If a singular interest rate (discount rate) can be identified for the decision maker selection of the optimum point on the frontier is relatively easy. The interest rate relates the relative values of returns in the two periods. That is, a unit produced in the first period is equal in value

---

[1]In speaking of community production possibilities what is called here the "production possibility frontier" is often referred to as the "opportunity line" or the "technical transformation curve" (14, p. 481).

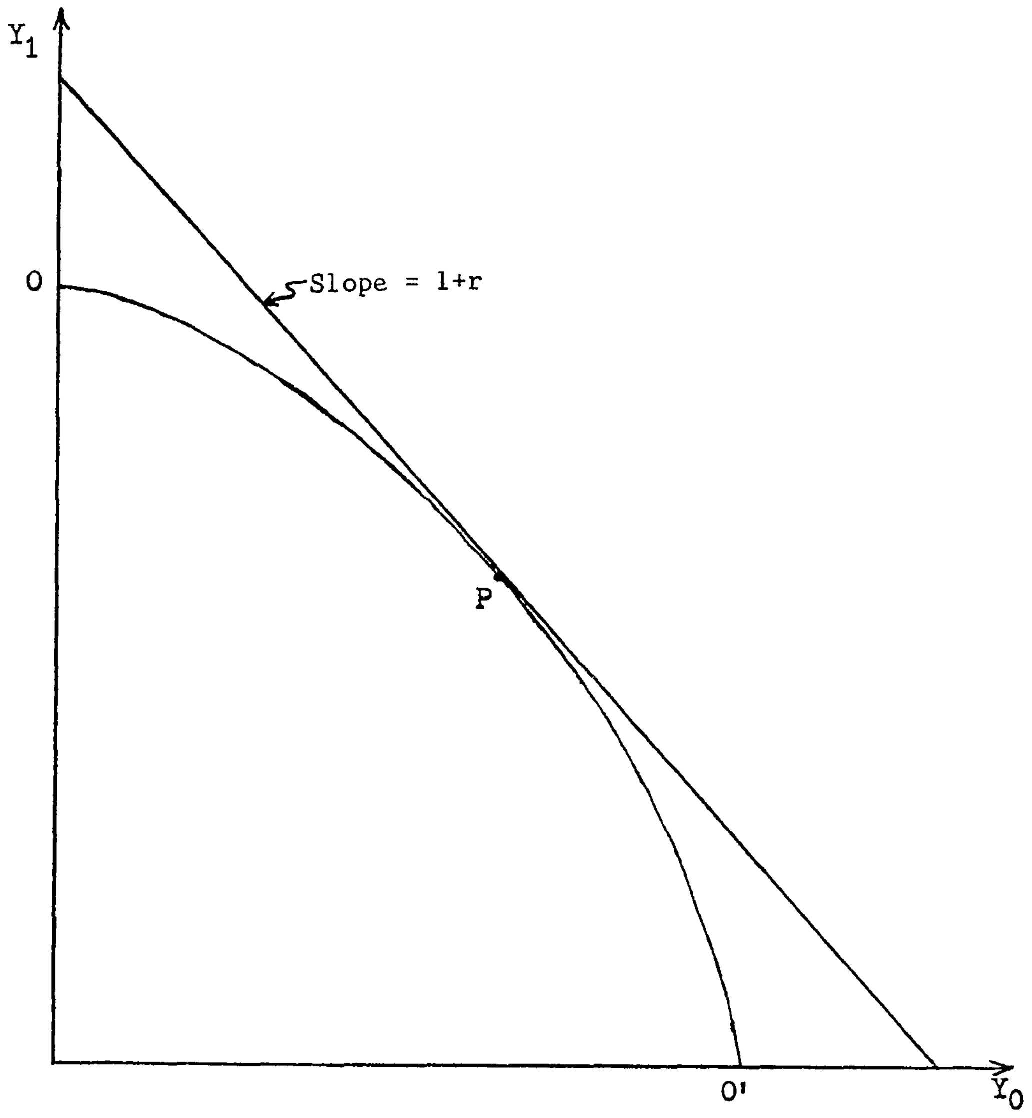


Figure 2.1. The optimum production point on a simple production possibility frontier under a singular interest rate

to this amount plus the fractional unit represented by the interest rate, of production realized in the second period. Therefore the optimum production point on the production possibility frontier is that point where the sacrifice of one additional unit of current production yields 1 + r times the gain in future production where r is the interest rate. At this point the slope of the frontier is 1 + r and is shown in Figure 2.1 as point P.

The selection of the optimum production point does not determine the consumption pattern of the decision maker, as indifference curves[1] can be added to the diagram. These indifference curves, which are convex to the origin because of the diminishing marginal utility of income, dictate whether the individual will be a borrower, a lender, or neither.[2]

Several modifications are needed in the model presented thus far, in order to give a realistic representation of the situation faced by an individual facing investment decisions in his own human capital. The first adjustment as presented in Figure 2.2 is the probable extension of the present output axis, Y_0, into the negative quadrant; a situation, possible but not necessary. Points in this negative quadrant represent current use of capital in excess of any output realized in the same

[1]These indifference curves are called "willingness curves" in traditional capital theory as they reflect the willingness to substitute future for present consumption.

[2]The line of tangency to the optimum production point, with slope 1+r, is drawn. If this line is tangent to an indifference curve to the right of and below its tangency with the production frontier the individual will borrow to this point. If the tangency is to the other side of the tangency with the frontier the individual will lend to this point. It is also possible that both tangencies will occur at the same point, in which case there will be neither borrowing or lending. This is based on the obvious assumption that the money market is perfect with borrowing and lending rates being the same. More thorough explanations of this analysis are widely available, such as that by M. Blaug (13, p. 481).

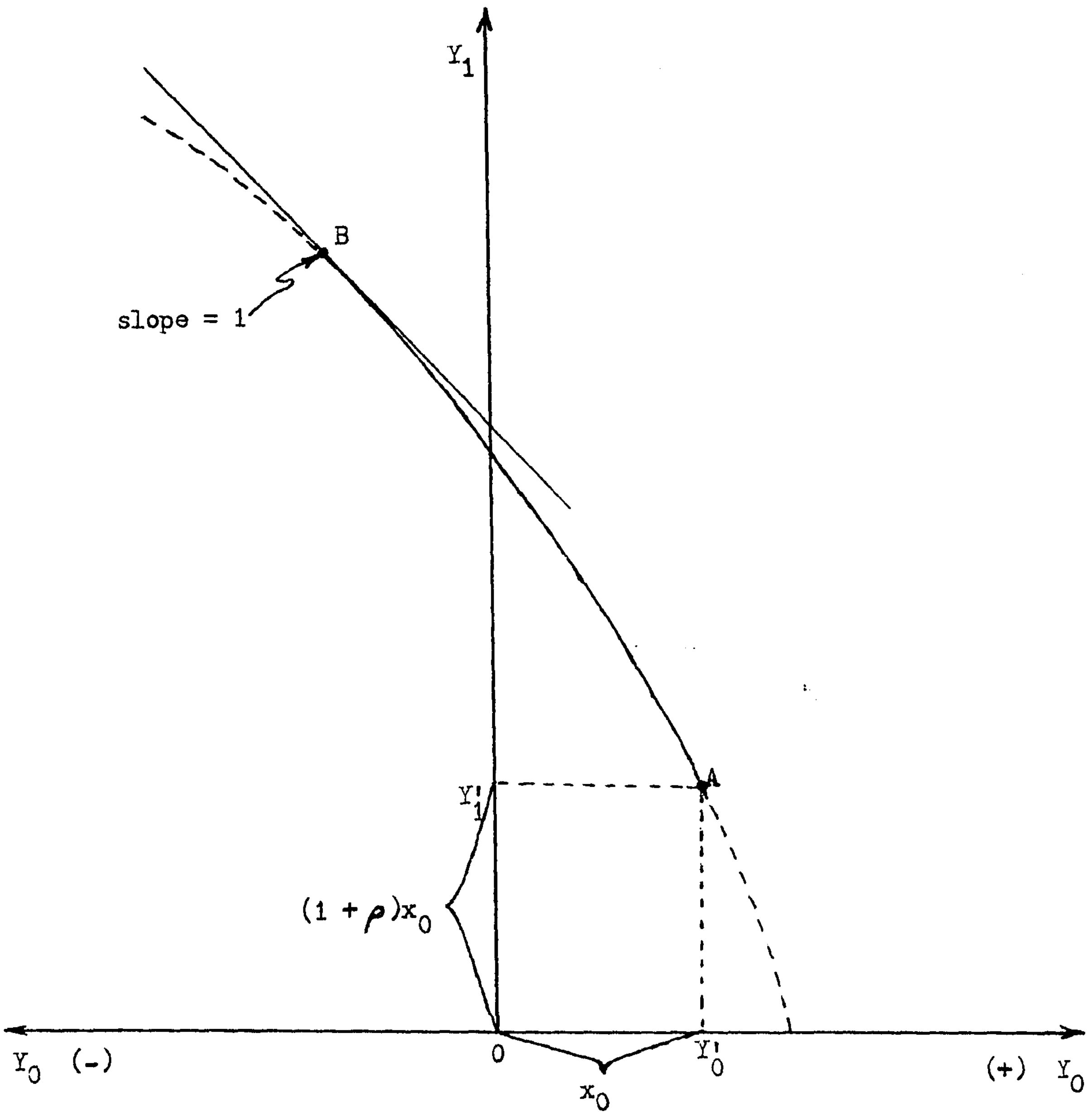


Figure 2.2. Extension of the production possibility frontier to the negative quadrant and its dual truncation

period. This situation of net capital consumption may be the usual case for those engaged in a full-time educational program.

Human capital in the form of knowledge and skills is not depleted through use. If a person is employed full-time in the initial period, investing nothing in human capital through organized educational programs, he would be expected to be capable of at least filling the same job in the next period. Thus, there is a point, along the frontier, beyond which it is not considered possible to substitute future output for present output. This point lies on the frontier where the distance along the Y_0 axis is equal to $1 + \rho$ times the distance along the Y_1 axis. The natural growth rate of income represented by ρ, is the rate at which income is expected to increase (if positive), or to decrease (if negative), when there are no additions to the stock of human capital. As shown in Figure 2.2, $OY_1' = OY_0'(1+\rho)$, or alternatively, $(1+\rho) = OY_1'/OY_0'$. The value of OY_1'/OY_0' varies from zero at the intersection of the production possibility frontier with the Y_0 axis to infinity at its intersection with the Y_1 axis. When these two intersection points are connected by a continuous function any value of OY_1'/OY_0' between zero and infinity can be found at some point along this line. The point with slope $(1+\rho)$, which is the right-most limit to the production possibility frontier for an individual making capital investments in himself, will be designated as point A. At point A no investments in human capital are made at the sacrifice of current income.

A second truncation of the production possibility frontier is made at the point B, where the frontier has unitary slope. To the left of this point, along the original frontier, losses in present production were compensated for on less than a one-for-one basis by future production.

The remaining frontier, if it has a finite length, has, at all points, a slope greater than or equal to one. This result is derived from the frontier being continuous and smooth with a second derivative which is never zero and a first derivative which is negative and continuous. The possibility exists that once point A is defined no portion of the frontier will remain which has a slope greater than one. Then the remaining frontier becomes the single point A (which can also be defined as B) since as A and B approach each other in the limit, they become the same point. This case represents a situation where no investment opportunities in human capital exist that have positive rates of return. Thus, the only alternative is to continue in the same job.

When the frontier has a finite length the interest rate, or rates, become important in determining the amount of investment in human capital, if any, that should be undertaken.

At this time it is re-emphasized that this analysis deals with a frontier. Therefore, the multitude of possible investment possibilities have been reduced to those yielding the maximum sets of returns as represented on the frontier. As will now be shown the interest rate is instrumental in selecting from this reduced set of investment alternatives.

If the person is confronted with a singular interest rate the analysis is identical to that of Figure 1, if the frontier contains a point with a slope of 1 + r. When the frontier has no such point the maximizing point is either A or B. If 1+r is greater than the slope of any point on the frontier the maximizing point is A. For B to be the maximizing point 1+r would have to be equal to or less than one. As this necessitates a non-positive interest rate and negative interest rates are considered as not feasible, B can be a maximizing point only if the interest rate is zero.

Figure 2.3 presents the production possibility frontier and two different lines tangent to the frontier, with slopes of $1+r_b$, and $1+r_l$, where r_b indicates the rate at which money can be borrowed and r_l, the rate at which money can be lent. The points of maximum consumption (i.e. "consumption possibility frontier")are represented by $R_lP'PR_b$. The production possibility frontier is a net concept measured by the gross output in the period, minus the intake of capital, net of consumption expenditures. Consumption expenditures are total expenditures minus investment expenditures. As a minimum level of consumption is necessary for sustinence, all consumption will be in the positive quadrant. Thus, anytime that the optimum point on the frontier lies in the negative Y_0 quadrant, borrowing must necessarily occur until the tangent to the frontier at the optimum point is also tangent to an indifference curve in the positive quadrant. (Consumption from accumulated wealth will be considered shortly.)

Figure 2.4 shows the three general cases which may occur when two different interest rates, a borrowing rate and a lending rate, exist. The indifference curves shown are from three different sets of indifference curves and are presented on the same graph only for illustrative purposes. In the case where R_lP' is tangent to U_l the person invests to P' and

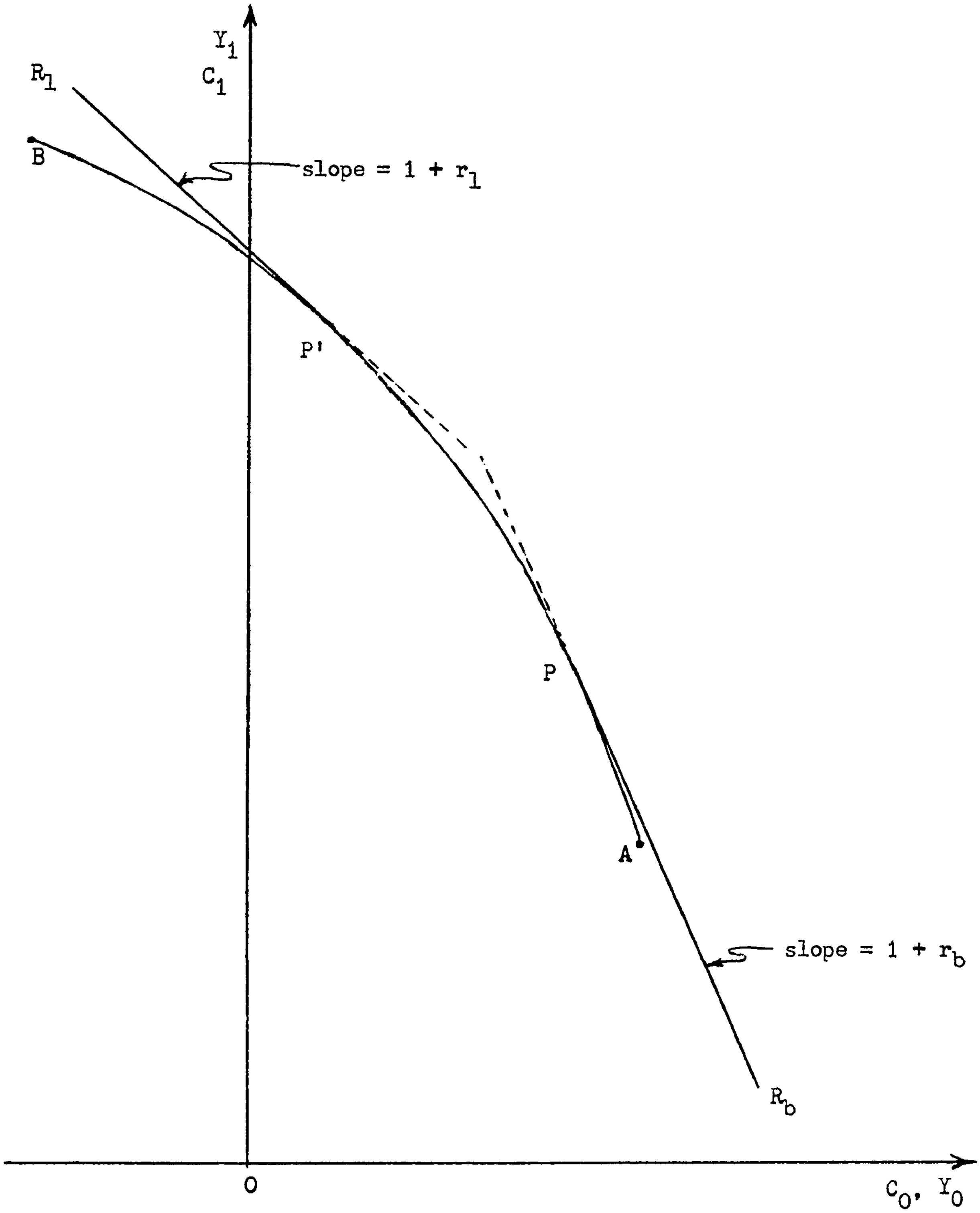


Figure 2.3. Extension of the production possibility frontier to a consumption possibility frontier

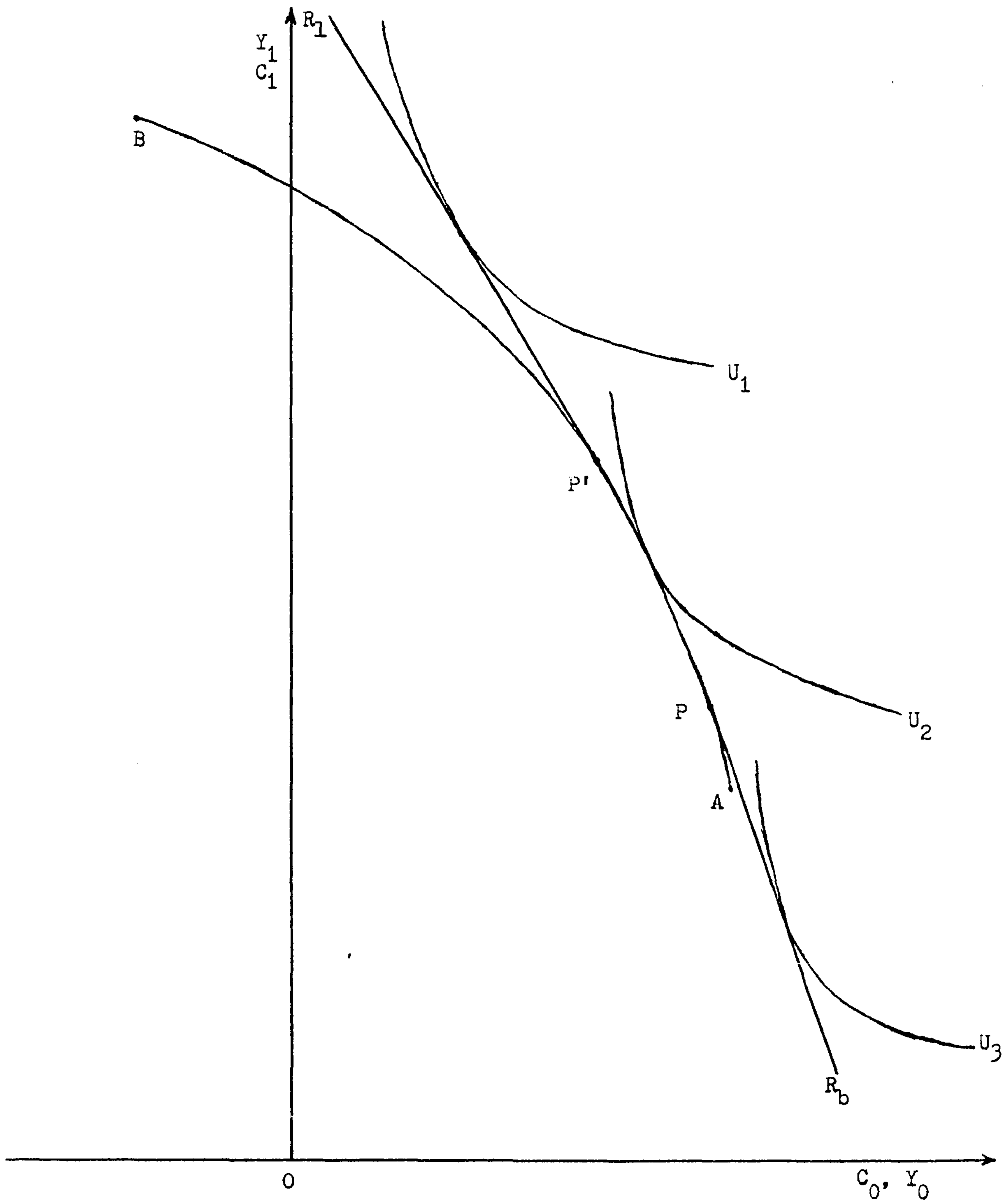


Figure 2.4. Production and consumption optimums combined

lends to the tangency point. The proper interest rate to use is the lending rate, r_l. Where PP' is tangent to U_2 the person produces and consumes at the tangency point. The proper interest rate is one minus the slope of PP' = the slope of U_2, which lies somewhere between r_l and r_b. Where PR_b is tangent to U_3 the person produces at P and borrows to consume at the tangency point, with r_b the correct interest rate.

Wealth holdings by the individual will now be added to the model developed so far. It will be shown that while holdings of wealth do enter the decision making with respect to investments in human capital, the basic analysis, as presented to this point, remains unaltered.

The incorporation of wealth into the model necessitates the separation of the output (Y) axes and the consumption (C) axes, as presented in Figure 2.5. Possible consumption in the initial period exceeds the amount of possible output by the initial wealth holdings, which will be designated as w_0. This results in a shift of the production possibility frontier to the right by the w_0 amount. Consumption possibilities in the second period exceed output possibilities in that period by the maximum quantity of wealth holdings in the period. The possible wealth holdings are the initial wealth holdings plus any yield from such holdings. Thus, possible wealth in the second period is $(1+r')w_0$, where r' is the average rate of return on wealth. A second shift of the production possibility curve upward by this amount furthers the transformation of the production possibility curve to a consumption possibility curve. This transformation is completed when the lines representing lending and borrowing possibilities are added. The orientation of the consumption possibility curve

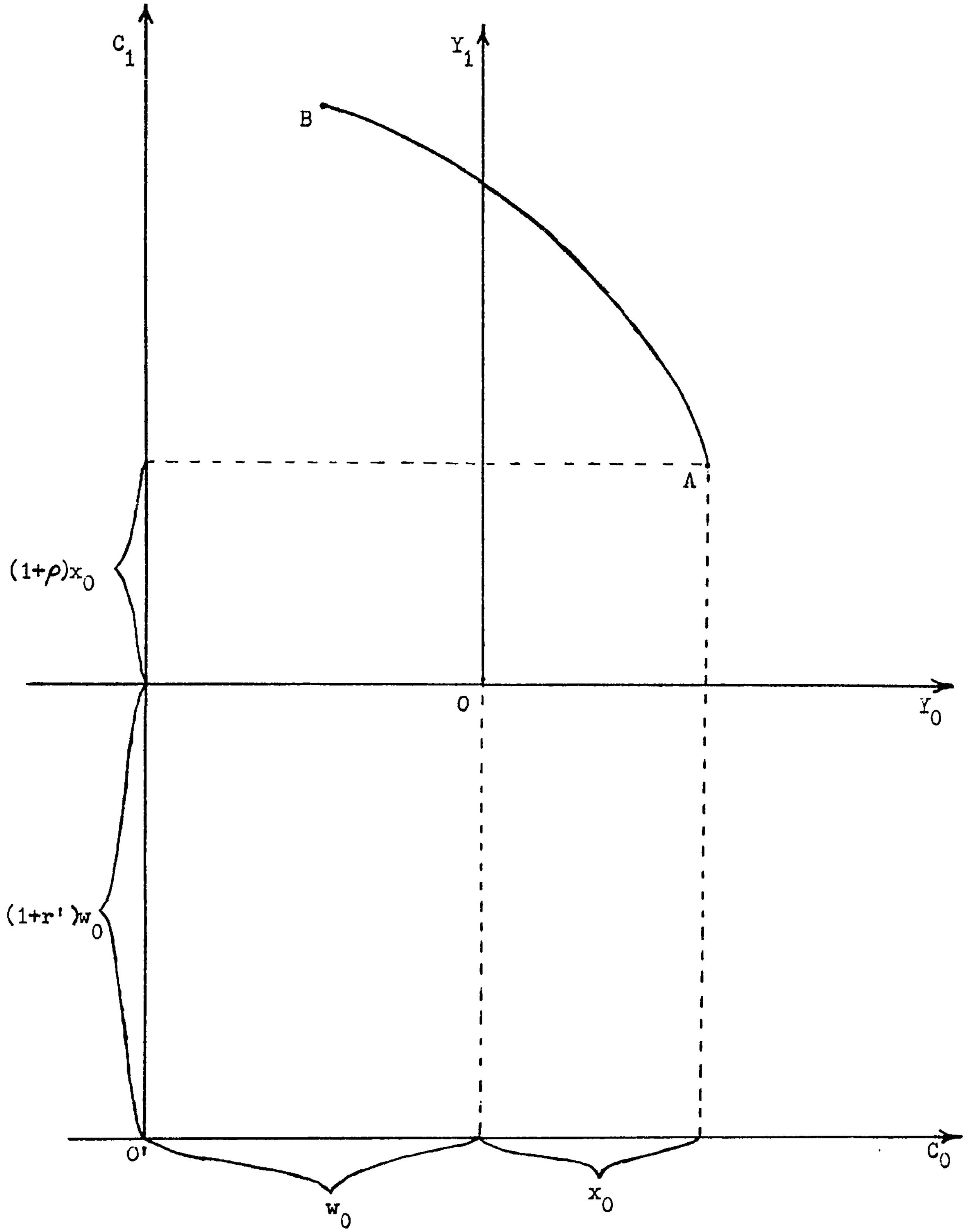


Figure 2.5. The addition of wealth to consumption possibilities

with respect to the consumption axes and the position of indifference curves with respect to the consumption possibility curve are added to the analysis by the addition of wealth. The remainder of the analysis relating to the relevant interest rate, remains unchanged from that formerly presented.

The addition of wealth presents the possibility that a person can be operating in the negative Y_0 quadrant and still be a net lender in the initial period, a result which was not possible before wealth was added.

What constitutes wealth will not be given a strict definition. Which elements of the total wealth are available for current consumption depends upon the motives for holding the assets (e.g. contingency balances) as well as liquidities and the time periods considered. Wealth is introduced to show that the model, developed under the assumption of no wealth holdings, is basically still valid when this assumption is relaxed.

While the model developed here parallels much of the traditional capital theory its application to empirical operations is limited by the use of only two time periods (6). An extension of the analysis to three time periods with a three-dimensional production possibility surface, two-dimensional borrowing and lending planes (to establish the consumption possibility frontier), and a set of three-dimensional indifference surfaces can be visualized and is on the outer bound of graphical capabilities. Extension into additional dimensions is equally relevant, where the dimension of such analysis would equal the number of periods considered.

The consumption pattern of the investor in human capital is not important in the following analysis, which has the objective of an optimum allocation of resources through the best investment policy. Attitudes toward consumption are important as they are ultimately expressed in the interest rate, indicating the relative levels of utility applied to consumption and indirectly to income or production in different periods.

If a person is a wealth-holder the marginal rate of return to additions to his wealth should reflect the rate at which he discounts future returns. Implicit in this statement is the assumption that wealth is held only for the consumption which it allows in a future period. Under this assumption the correct rate to discount returns to investments in human capital is this same marginal rate, which will be designated as r, not the average rate of return to wealth, r'.

The effectiveness of special educational loans at a low interest rate can be analyzed within the structure of the model which has been developed. Figure 2.6 presents the situation where such special loans are available in quantities as large as the present total cost of the investment. These loans at a rate r_e, where $r_e < r_b$, mean that a person can borrow to a point with a Y_0 coordinate equal to that of point A. From this asset position he has the options of borrowing or lending to his point of maximum utility. A person faced with this possibility will always borrow the maximum possible as this extends his consumption possibility frontier to its fullest. Thus, a person would borrow to the point Q', and consume at that point if his indifference curves looked like that rep sented by U_2, would borrow, at interest rate r_b if his indifference curves were

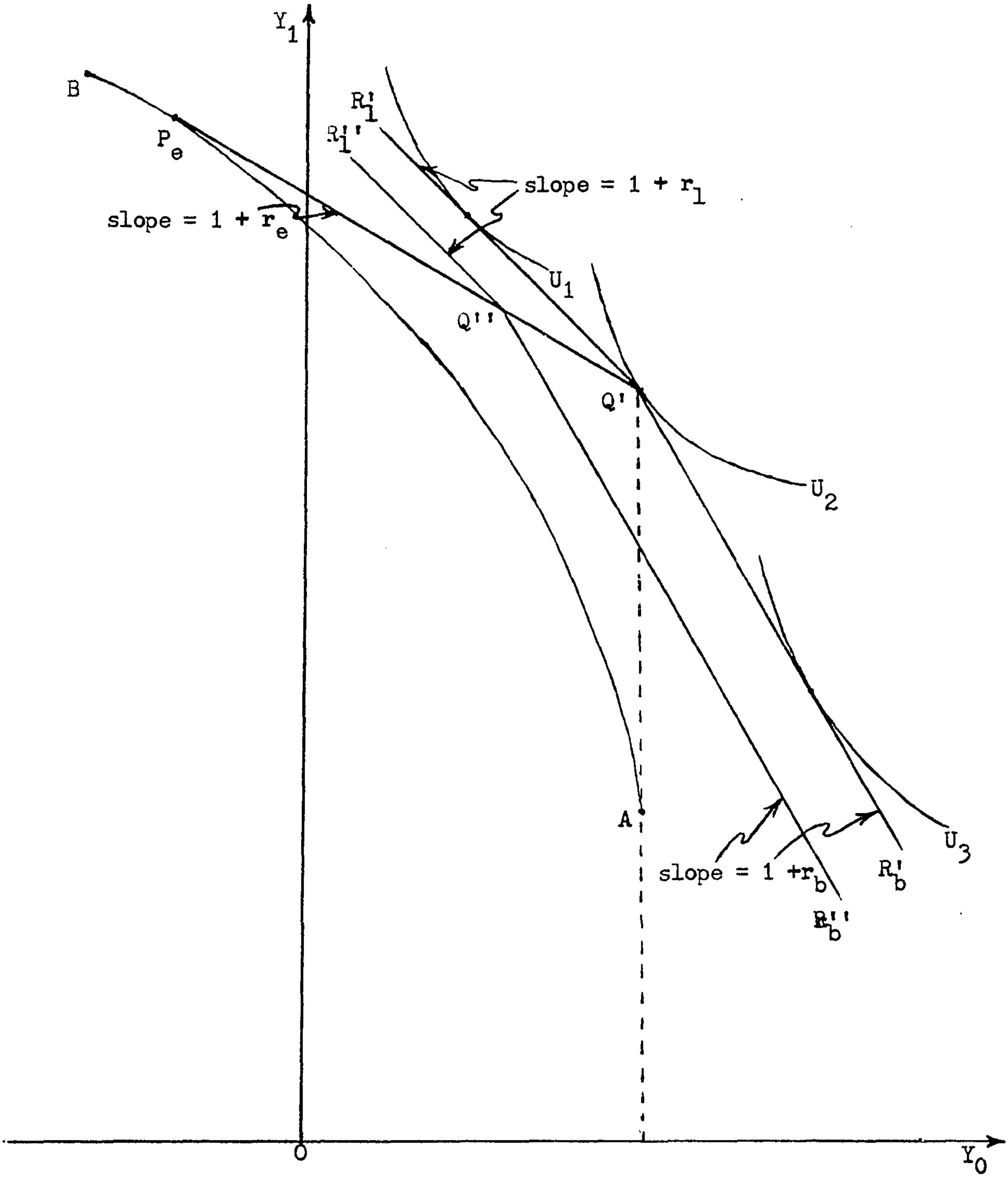


Figure 2.6. Extension of the consumption possibility frontier via low-interest educational loans

represented by U_3, and would lend, at interest rate r_e, if they looked like that represented by U_1. Borrowing any quantity less than the maximum possible would only lead to a constriction of the consumption possibility frontier, as represented by $R_1''Q''R_b''$. It should be noted that in all the cases presented the low-cost loans have resulted in an increase in educational investments.

There are cases where educational loans at this low rate will not stimulate educational investments. The first such case is where the production possibility frontier is either a single point or has a slope which is, at all points less than $1 + r_e$. For these cases there had been no educational investment before the loans were made available and the low rate was not sufficient to stimulate such investments. In the case of a single point production possibility frontier no interest rate could stimulate such investments.

A second situation where low-cost loans fail to stimulate educational investment occurs when a person initially faces an imperfect money market, with $r_b > r_1$. When the slope of the production possibility curve at the pre-loan maximizing point is less than $1+r_e$ the low-cost loan fails to stimulate investment. Such a situation is presented in Figure 2.7 as $1+r_e$ is less than the slope of the production possibility surface at its tangency with the indifference curve, U. Investment could be stimulated at a lower interest rate, r', where r' is less than the initial discount rate.

Another case where low-cost loans fail to stimulate educational investment occurs when the assumption that such loans are available in

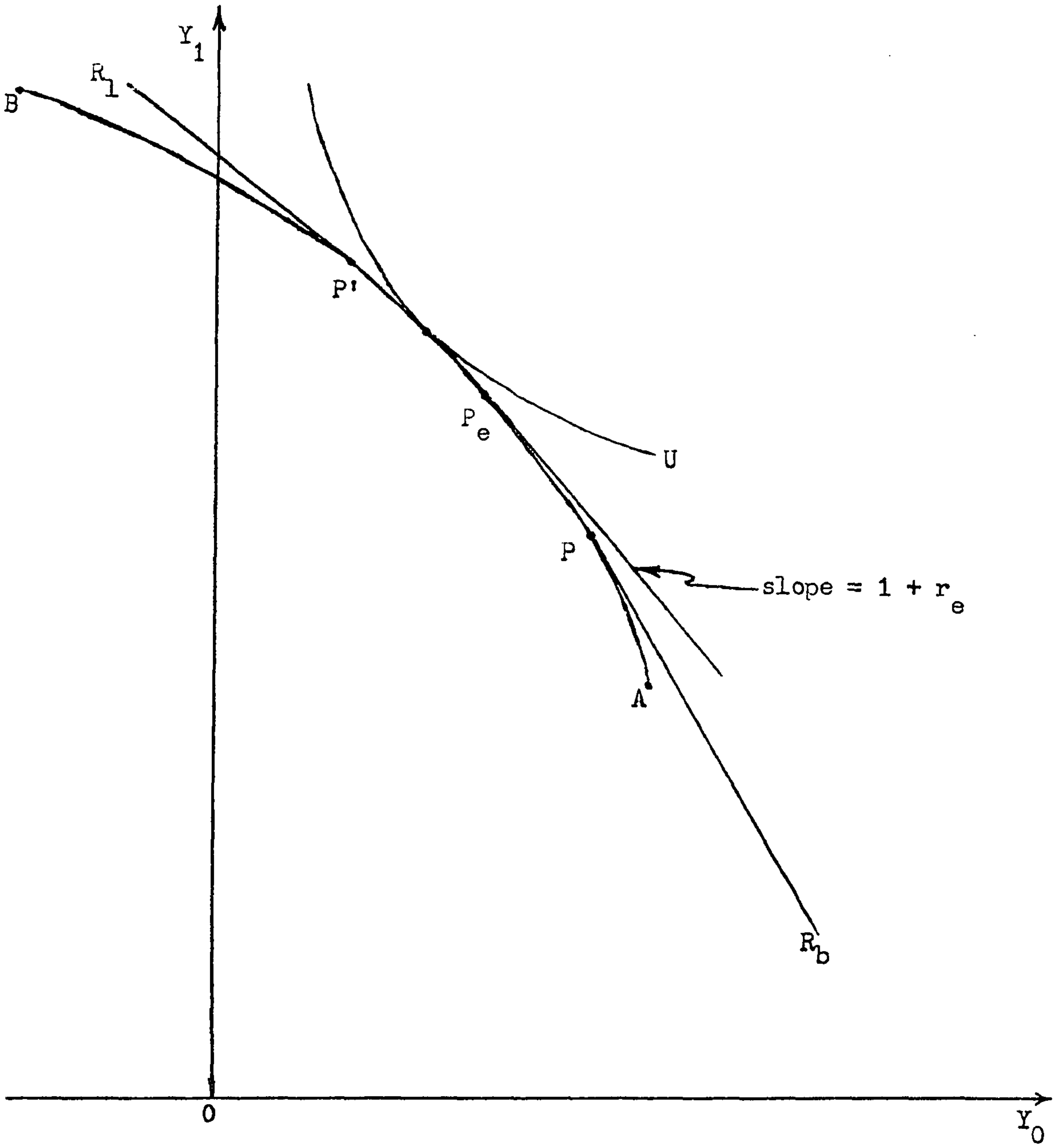


Figure 2.7. A failure of low-interest loans to stimulate educational investments

quantities adequate to compensate for all current income forgone, is dropped. Figure 2.8 shows that there is a critical quantity a low-cost loan must equal or exceed to induce an increase in educational investments. A loan of quantity Y_pY_1 results in the consumption possibility frontier R'R' which is contained within the frontier RR, which is achievable without such a low-cost loan. With an available loan of quantity Y_pY_c at interest rate r_e, the decision maker is indifferent between borrowing and not borrowing. Only if loans of a size greater than Y_pY_c are available, such as Y_pY_d, will such loans induce additional educational investments. While Figure 2.8 assumes a perfect money market this is not necessary as an identical analysis is applicable to a market with $r_b > r_1$.

B. Personal Discount Rate

"The present-value of an individual's future income depends upon the individual's preference for present consumption. However, when considering investment as a means for increasing future income, the investment may be financed from past savings, current income, or by borrowing. Thus, the cost of financing an investment may be determined by an individual's time preference for consumption (expressed as a rate), the rate of return that could be earned if alternative use is made of accumulated resources, and/or the rate at which one may borrow additional resources. Since these rates vary among individuals and groups that differ in wealth, age, etc., no single interest rate can be said to represent the cost of financing an investment for that group" (20, p. 30).

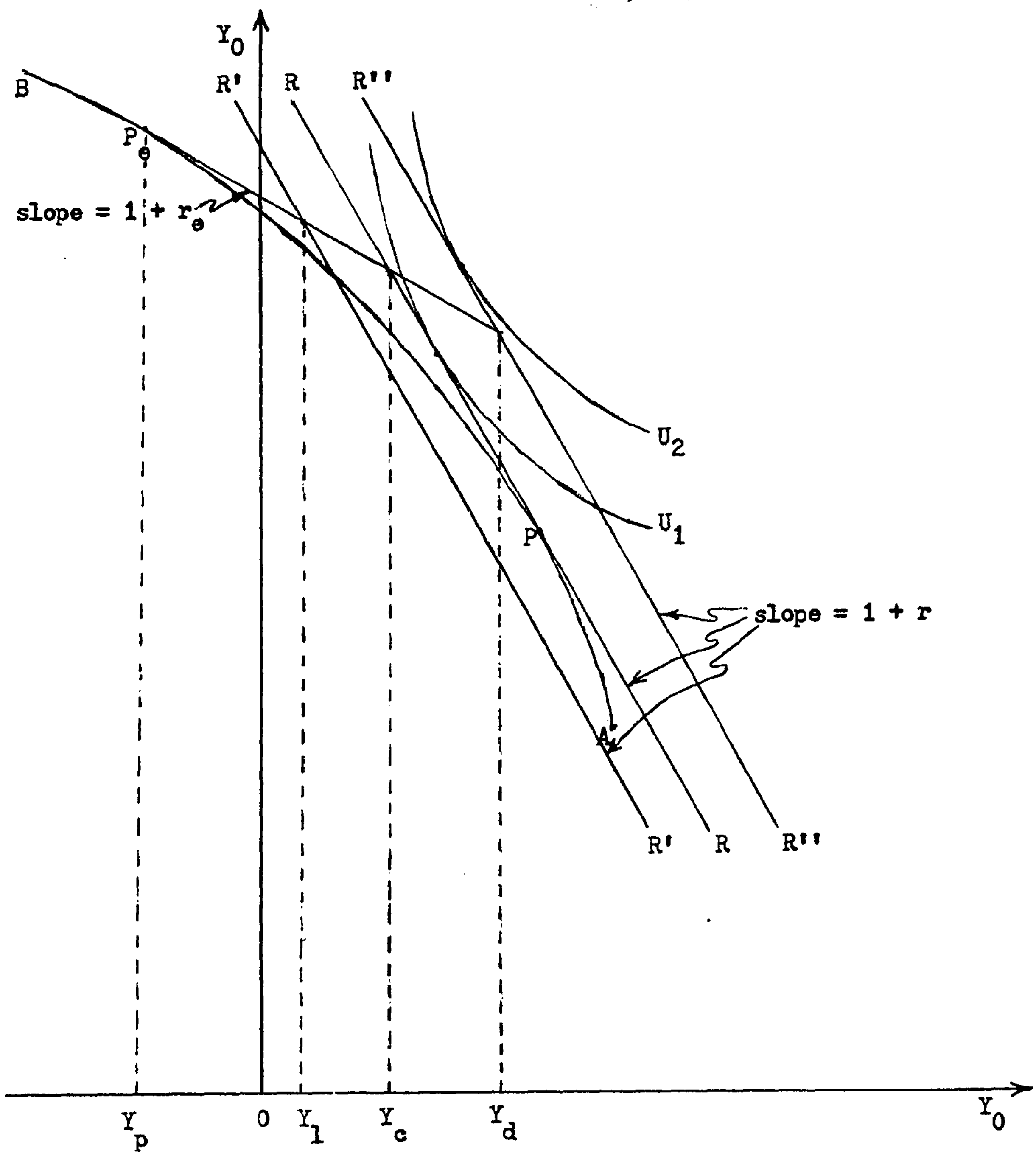


Figure 2.8. The critical low-interest loan necessary to induce additional educational investment

The above paragraph is consistent with the ideas expressed by Hirshleifer (36), and in the preceding theoretical construct. That is, there is no single individual discount rate and the rate for any individual person lies somewhere in the range, from his possible return on a riskless investment to the return he must pay for borrowed funds.

In an equilibrium situation there exists only one interest rate, and not three. This means that a person would not be borrowing funds when he is presently holding assets on which the return is less than the marginal borrowing rate. (The borrowing rate in the following discussion is this marginal rate.) He also would not be in an equilibrium situation if the return rate on investments is greater than the borrowing rate; for in this situation he would continue to borrow funds and invest them at a higher return. Thus, the marginal return on investments is equal to the borrowing rate for a person who is observed to both borrow and invest. The borrowing rate is then the correct rate to use to discount returns from educational investments of such an individual.

If a person is a borrower the only obvious rate of discount for educational investments is the borrowing rate. If, instead he is a lender the lending rate should be used to discount educational investments. If he is neither a borrower or lender all that can be said is that the correct discount rate lies somewhere between the borrowing and lending rates.

Since all people who have funds to invest can get a certain minimum guaranteed return, say five percent (14, p. 31), this same floor can apply to all personal discount rates. Under the assumption that people, particularly those who are willing to invest at the minimum rate, are risk averters, a positive risk factor should be added to this riskless rate. When educational investments are considered the risk factor should be particularly important as there is much uncertainty as to the absolute amount of future returns, the possibility of not being able to fulfill the educational requirements, and the actual job content and requirements.

C. Returns to Education

The most general economic assumption, that man is continually striving to maximize and that the economic man strives to maximize income, will also be a basic premise here. The assumption that, "an individual chooses that occupation for which the present-value of his expected income stream is a maximum" (11, p. 35), a more specific statement of the same assumption, but specific to the use of human capital, is applied in this work. Also included in this study is the assumption that a person wishes to choose that occupation and that method of qualifying for it, which maximizes the present-value of his expected income stream. Within this assumption provisions will be made for making adjustments for personal preferences, risk attitudes, etc., as will be explained later.

Many of the other studies in economics of education concern themselves entirely with returns to formal (i.e. general) education, disregarding the other methods of investing in human capital through education. By dealing only with formal education it is possible to assume only one type of education in a time continuum. Within this framework, rational people continue their investments in formal education until the rate of personal return on these investments equals the personal discount rate. This method of arriving at the optimal level of educational investment is based upon the assumption of decreasing returns to education, an assumption that has received some support (8, p. 82), but is not universally accepted. The opposite assumption, that education yields increasing returns, is supported in a regression analysis done by Becker and Chiswick (10). This study indicates higher returns to more than twelve years of education than to eight to twelve years, and higher returns to eight to twelve years than to under eight years.

Expected net discounted returns help determine the type and quantity of individual investments in education. These returns are wholely those reaped by the individual. Returns to society may differ from the sum of the returns to all individuals. Extra returns to society may be caused by externalities resulting from the individual investment decisions, social weightings of returns to different individuals, social weightings of other characteristics of society (e.g. freedom of choice), or innumerable other items. When considering an individual's marginal addition to the social welfare function, the major contributions are any externalities to others, adjusted by their social weights and summed, plus the return to the individual multiplied by his social weight. Under the social viewpoint that all people are equally important each dollar of income might be given an equal weight. Then the social maximum is that situation where total returns to individuals are maximized. A more realistic viewpoint might be that the net social benefit of an additional unit of personal income is some function of the income of the recipient. If income before taxes is used to measure individual returns it might be assumed that the regressive nature of the income tax system makes the necessary adjustments to give units of gross personal income equal social weight.

If externalities are ignored it would then appear that when all individuals act so as to maximize their incomes this would result in a social maximum, as well. There are a number of reasons which make this conclusion incorrect. The relative valuation of present and future returns can differ greatly among individuals, meaning that there is not even an individual discount rate to compare the social discount rate against. Restrictions may exist which keep individuals from investing in education to a level which would be deemed socially desirable. The lack of available sources of money could make the cost of investing in education too high. This could take the form of a complete lack of additional funding, as indicated by an infinite interest rate.

The divergence of individual and social discount rates and the existence of measurable external returns which are not considered by an individual decision maker, might be referred to as quantifiable barriers to the equating of social and individual optimums. Another class of barriers, nonquantifiable barriers, can also be identified. Informational barriers about job availabilities, requirements, and payoffs constitute a major portion of these informational barriers. The other set of nonquantifiable barriers are artificial institutional restrictions. Barriers exist to entry into particular educational programs which are not based on the abilities of prospective entrants to acquire the associated skills. Some of the skilled crafts and certain professions which have a large amount of control over the educational programs leading to entry in their occupations are often cited as examples. Another artificial institutional restriction exists in hiring practices which restrict the numbers of entrants and choose employees on the basis of factors which are not important in the performance of the particular job.

Another set of factors which influences the quantity and type of education chosen by an individual might be called individual tastes. Such tastes are functions of both social pressures, and individual preferences formed aside of the influences of social attitudes (e.g., while an automobile salesman may be paid better than a bank teller the bank teller may have a higher social ranking). Without trying to delve into the mysteries of how individual tastes are formed it should suffice to note that direct social pressures are probably only a minor influence in the occupational selection procedure of most persons. The actual duties of a job may not be the only factors considered in determining the ranking of the job in the set of job possibilities. The location of the job may be an important factor. Transportation costs can be considered as reductions in the payoff and thus are not the cause of this location preference. Family and community ties and geographical preferences are also prime factors behind these attitudes.

It will be noted that the concept of returns is given an extremely broad meaning when these attitudes to particular job characteristics are included as returns. All further references to returns will be to quantifiable returns only and will exclude the nonquantifiable psychic returns.

III. DEVELOPMENT OF AN ANALYTICAL MODEL

A. Background and Problem

The analytical model used represents an ordered look at the possible combinations of training and employment available to a given individual at a particular time. These combinations are treated within a maximization framework where the object of the individual is assumed to be maximization of the present-value of net returns. The model incorporates both educational costs and job payoffs. Possible combinations of job training (both general and vocational education) and occupations are established from information about job entry requirements. The analytic model is formulated in such a manner that, anytime the parameters of the model are found to differ from those originally postulated, the identification of an optimal investment path can be re-evaluated.

1. The itinerary model

In its broadest sense the problem posed could be considered an itinerary problem. Thus, the itinerary problem is used as the first step in establishing the analytical model.

Within the itinerary problem a number of sites exist with payoffs which are a function of time. (The inclusion of variables, in addition to payoffs, is possible.) These sites are connected by routes which are identified by a cost and their beginning and ending points, which are both sites. The first step in identifying the optimal solution for such an itinerary problem, on a time continuum, is to allow movements between sites only at specific times. Such times exist when the payoff rate at the site of arrival, at the arrival time, exceeds the payoff rate at the site of origin, at the departure time, by the amount of transportation cost, and the former is rising at least as fast as the latter (29, p. 5). This step is not necessary when all possible departure and arrival times are discrete. Once the points at which movements can be made are identified dynamic programming can be used to select the set of movements which will maximize returns (i.e. give the best itinerary). In the situation where movements to new activities at finite times are possible, the following procedure is used to identify the maximum payoff from a given initial point and the itinerary which achieves that payoff.

$$U(L_i, t_i) = \text{Max} \left\{ \begin{array}{l} \int_{t_i}^{T} V(L_i,\ t_i)dt \\ \text{Max}_j\ (U(L_j,\ t_j) - C(L_i,\ t_i,\ L_j,\ t_j) \end{array} \right\}, \text{where} \qquad (3.1)$$

$U(L_i, t_i)$ = maximum payoff from being at site L_i at time t_i

T = time horizon

$V(L_i, t_i)$ = payoff of site L_i at time t_i

j = index of possible alternative sites

t_j = arrival time at alternative site L_j

$C(L_i,\ t_i,\ L_j,\ t_j)$ = transport cost to L_j at arrival time t_j.

The optimal solution is identified by backward recursion, where the additional payoff to be derived at time T, the time horizon, is zero (i.e., $U(L,\ T) = 0$). The procedure of this backward recursion is illustrated in Figure 3.1. In this example four sites and a number of

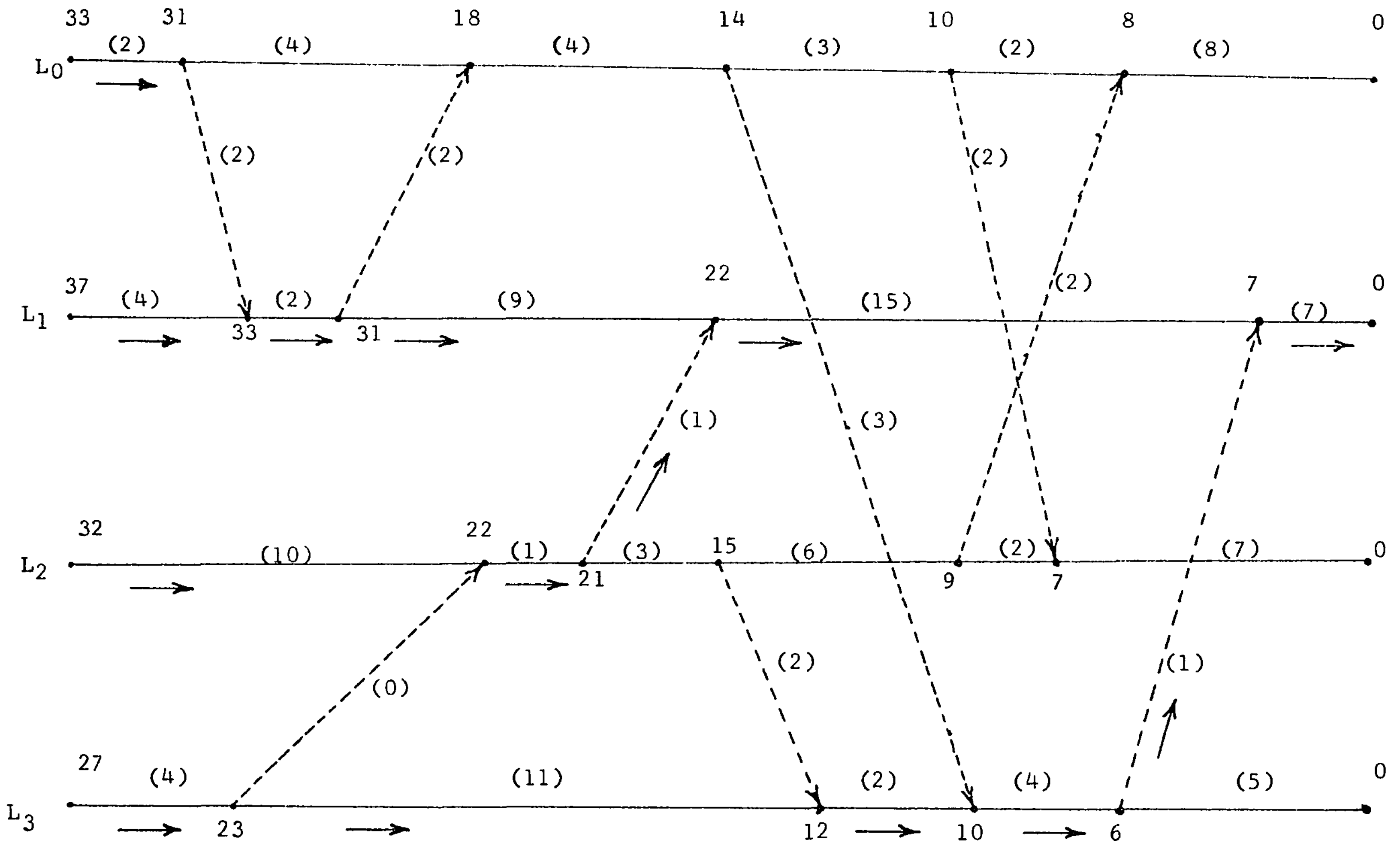


Figure 3.1. Optimal routes in a four-site itinerary model

feasible crossings are identified. Bracketed numbers represent costs along broken lines while they represent returns along solid lines.

Moving backward, to the left, from the time horizon, T, each end point of a movement is given the value of the sum of the value of the next event point to the right, whether the origin or the end of a movement, and the intervening value of the activity. The value of a starting point for a possible movement is the maximum of the value at the end of the move minus the movement cost, over all the possible movements from that point, where no movement has a positive value as a movement cost. Arrows indicate the optimum choice when a decision must be made, whether or not to move to a new activity. Following the arrows from any given starting point indicates the optimal route from that point. The unbracketed number indicates the value of the best itinerary from that point.

Itinerary models can be formulated in many ways, with the simple time continuum model just presented being only one of these. This simple model illustrates the basic structure of the itinerary models and will be shown to have characteristics in common with a possible model for human capital investments.

The itinerary model was first formulated to deal with migration problems, where the usual situation has sites with positive returns and movements between sites with negative valued costs. In a human capital model the sites, with their positive values, could be redefined to be occupations with returns in wages. In the same light the movements between sites can be redefined as educational investments which are necessary to move to the new occupation. Occupations must be arranged in a quasi-hierarchial structure, where a movement up the hierarchy involves a cost, but the opposite movement, back down the hierarchy, can be made instantaneously, with no cost. This is not a real hierarchy since all occupations are not comparable. As an example, there may be a hierarchy of welding occupations demanding increasingly higher levels of training and a similar hierarchy of carpenters. Movements from the highest level of either hierarchy to the lowest level of the other might involve some training cost. If a movement in the opposite direction had been previously made no cost would be involved. This points up the major problem which would be encountered if one uses the itinerary model as a model for human capital investments.

The major problem arises when the cost of moving between occupations at any time is affected by previous training. This means that the value of being at a particular point may depend upon which path was used to reach that point. Thus, backward recursion as used in the itinerary problem, is limited in use because that model assumed that the value at a given point was independent of how that point was reached.

While the previous problem is sufficient to make the itinerary model inappropriate as a generalized human capital investment model, there are further shortcomings of the model which can be noted briefly. Added reasons exist which make the value of any possible point not wholly dependent upon the forward path. The value of staying at a particular occupation from time t' to t" can depend on whether a person had been in the occupation previously, or was an entrant at time t'. It might be expected that the payoff in a particular occupation is an increasing function of the time spent at that job. Thus, the method of arriving at a point can determine the value of staying in a particular occupation as well as the cost of moving to another occupation.

Further, the possibility exists of one moving to any job with entry requirements the same or lower than those of the present occupation. This indicates another inadequacy of the simple itinerary model in application to educational investments.

2. The PERT and CPM methods

An optimal path model which is designed to allow constant reevaluation, a characteristic desirable in application to educational investments because of the likelihood of parameter changes, needs consideration here. The model, PERT (Program Evaluation and Review Technique), and a very similar model, CPM (Critical Path Method), are widely used by business in scheduling elements of a project. These methods, which are designed to shorten the time to completion of a project, allow reevaluation at each step of a project (3, 54, 73, 80).

The difference in the PERT and CPM methods lies in their emphasis rather than their techniques. CPM emphasizes the identification of the activities in a project which are critical to the completion time of the project. This identification then shows the elements of a project which should be given special consideration and, perhaps, to which more resources should be allocated. PERT deals with the same identification of the path of critical projects as does CPM. In addition, PERT emphasizes the manner in which the critical path may change through the life of a project as parameters are found to differ from their original estimators. As the procedures are so nearly alike the single term of PERT will be used to designate both CPM and PERT models in all succeeding references.

The simple graphical model of Figure 3.2, illustrates the procedure of PERT. PERT differs from the itinerary model because the goal is to identify the path of longest expected value rather than the minimum cost path. However, the basic structures of the two systems are identical. They both consist of arrow elements (activities) which represent procedures with quantitative measures, and circles (events) which represent the junctions of activities. In PERT, activities represent work programs which are the component parts of the particular project which the entire model represents. The values placed on these activities are the expected times required for completion of the particular activities. The sequencing of these particular activities shows the cumulative nature of the project, as certain activities must be completed before others can start. Looking at Figure 3.2, activities 1-2, 1-3, and 1-4 have no prerequisites, but 1-4 is a prerequisite for 4-5 and 4-7. Activity 1-3 is a prerequisite for 3-5, while 3-5 and 4-5 must both be completed before activity 5-7 can start. Activity 1-2 is a prerequisite for activity 2-4 and activity 2-6. All projects are linked in this manner to form the overall project. The events serve only to mark the ends of activities (projects). Their numbering provides a method of identifying activities and shows the sequence in which the

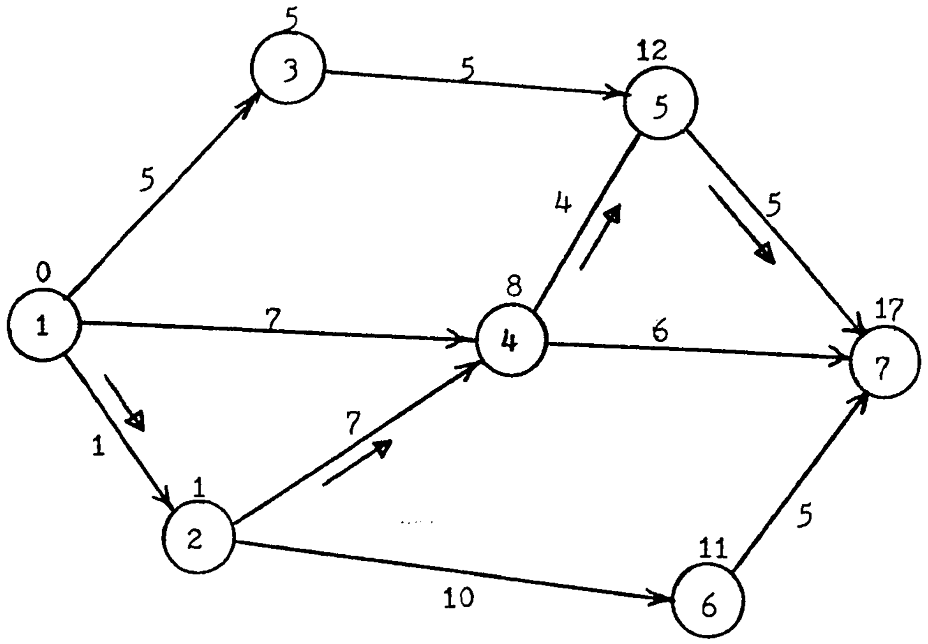


Figure 3.2. A simple PERT system at initial state

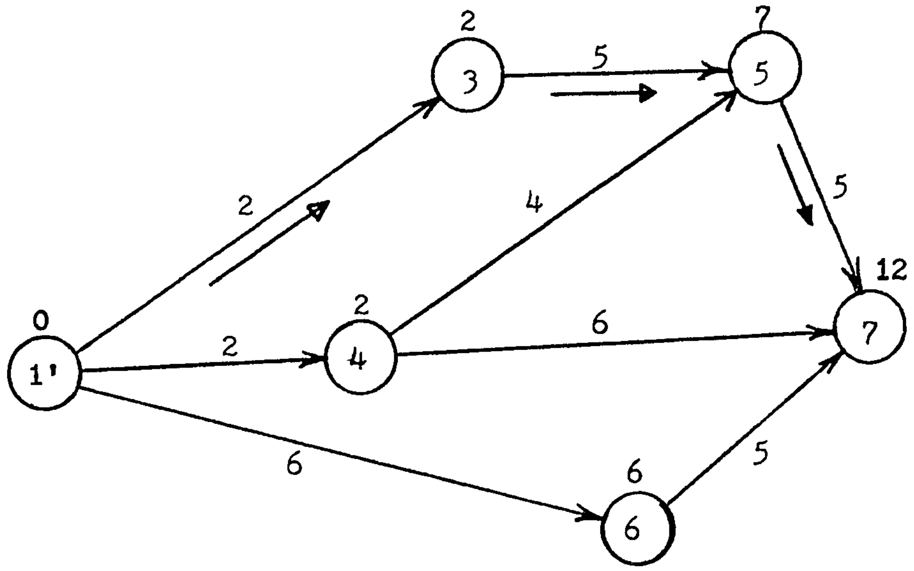


Figure 3.3. A simple PERT system after a parameter change

activities appear. Thus, a listing of all activities by their expected length and their start-event and end-event, would contain all the information which is conveyed by Figure 3.2.

The critical path of a PERT network is the chain of activities, between the start-event and end-event, which has the largest total value. This critical path identifies the shortest length of time in which the project can be expected to reach completion. Each event can be assigned a value which is the length of the longest path between itself and the starting event. The value of each event is calculated by adding the value of each activity for which it is an end event, to the start event value for that activity and choosing the maximum of these sums. The procedure is analagous to that used in the itinerary problem, except that it is a maximizing technique to the left rather than a maximizing technique to the right. The critical path is that chain of activities, leading from the start-event, which, when their values are summed, yields the value of the end event.

The re-evaluation feature of PERT is illustrated in Figure 3.3, where the program of Figure 3.2 is repeated, but at a certain length of time after its start. In Figure 3.3 activity 1-4 is two units away from completion, 1-2 is completed, 2-6 (now 1'-6) is six units from completion, but 1-3 has taken longer than originally expected and is still two units from completion. A re-evaluation shows that the critical path has changed from that originally expected as represented in Figure 3.2.

B. A Model of Individual Educational Investment Opportunities

Continuously throughout his life, but more meaningfully in his earlier years, a person is faced with many possible choices with respect to spending his time in further education, or entering the labor force. Educational possibilities exist in continued formal education and many vocational training programs. What educational and occupational possibilities are open to a person depends, in part, on his former education. Thus, educational programs and occupations can be presented in a system where prerequisites are defined in terms of the educational programs which must be followed for employment in particular occupations. In Figure 3.4 a very simple model is presented with two levels of general educational and several vocational training and occupational options. A_{12} and A_{23} are the two general educational options. The events E_1, E_2, and E_3 represent leaving the general education activity to enter vocational training, work, or a higher level of general education. In this education model all occupational activities end at the retirement event.

In this simple model each activity is identified by two subscripts which indicate its start and end events. In the more advanced models a third subscript will be added as more than one activity can exist between the same two events. Such situations occur when moving directly from the general education system to an occupation.

The activities with 8 as the last subscript represent employment which commences when the educational system, both general and vocational, is left, and continues until retirement. Retirement is represented by

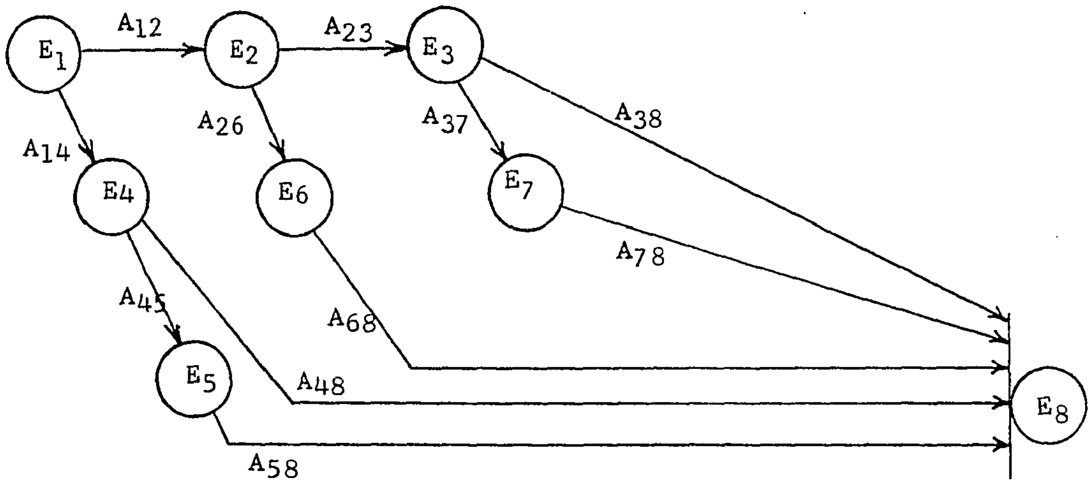


Figure 3.4. A simple educational investment model

the event E_8. In application of the model, employment activities were identified by their entry requirements and expected rates of job advancement, as well as job content. Occupations were so defined that upward movement from the entry level was expected and thus such movements did not need to be explicitly incorporated into the structure of the model, as additional flows. This expected rate of job advancement, after job entry, is based principally on the payoff expected from job experience. Such advancements might also mean changing to a completely new occupation. All such expected movements and their corresponding salary or wage increases are anticipated in the single occupation identified at entry.

The education model, as presented in Figure 3.4, is very similar to the PERT models of Figure 3.2 and Figure 3.3. However, one very important restriction has been added to the PERT format: only the last event in the entire system (i.e. the retirement event) can be an end event for more than one activity. This is done because each activity is identified by its discounted value, where this value depends upon the time in the future at which the activity is expected to start (which is the time of its start-event). Each start-event, except the very first, is also an end-event. The time of this start-event is the time of the start-event of the activity for which it is an end-event, plus the length of time required to complete the former activity. If a single event were the end-event for more than one activity, its value would not necessarily be unique. In such a case the value of all activities preceding that event are not uniquely defined. The procedure of discounting returns, which assigns a unique value to each activity, is elaborated in a succeeding part of this chapter.

The objective of the education model is selection of a time path of educational investments and employment which will give a person the maximum expected value of discounted income. This expected value of discounted income was identified by its present-value.

The first step in formulating the educational model is to identify each occupation by its educational requirements for job entry, in terms of both general and vocational education. The identification of these prerequisites establishes the pattern of possible flows among education and occupation activities. Once this pattern of flows is established each activity must be valued before the path giving the maximum present-value can be identified.

Educational activities are identified by their length and cost per unit of time. Occupational activities are identified only by their return per unit of time. Since occupational activities are assumed to last until retirement, their length is determined by the time of job entry and the entrant's age. For this reason the age of an individual facing these decisions, is one characteristic which must be known before values can be placed on occupation activities in the education model. This means that an optimal path cannot be defined exclusively on the basis of cost, return, and time information about each activity. If at least one individual characteristic, such as age, were not important, the simple educational model would identify a single path which would be optimal for everyone presented the same options.

1. Educational Investment Model I

In Model I some simplifying assumptions are made to facilitate presentation of basic procedures. In Model II some of these assumptions are relaxed.

The first simplifying assumption for Model I is that a single interest rate can be identified which holds for all individuals and into all time periods until retirement. Individuals are assumed to disregard any chances of death or disabling injury occurring before retirement age (A disabling injury is defined as one which would render a person unemployable in his chosen occupation). In Model I, entering individuals are assumed to have none of the education represented by educational activities in the model. That is, the model will be used only for people entering the path of activities at event E_1 of Figure 3.4. It is further assumed that individuals expect never to return to full-time education after entering an occupation. Also, the individual must have the necessary mental and physical aptitudes and capabilities to fill any of the occupations presented in the model. Model I disregards risk as an element of cost to the job entrant.

The simple model presented in Figure 2.4 will be used to illustrate the format of Model I. The activities A_{38}, A_{48}, A_{58}, A_{68} and A_{78} represent all occupations for which this individual has the mental and physical prerequisites and in which he also has an interest. The values applied to returns from the various activities were calculated by the present-value procedure. When each activity is given a value the optimum path is defined as that path which has the maximum total of activity values.

As Model I made no provision for personal attitudes toward particular occupations, except that all those considered were acceptable to the entrant, a reasonable addition to the model would seem to be a weighting for relative subjective valuations of occupations. An alternative to such relative valuations, in a system such as Model I, or a more complicated system, where such measures are not available, would be a ranking of occupational paths by their present-values. Such a listing would allow the entrant to select the most attractive combination of present-value and occupation. As this model of education, occupation, and individual investment was not designed nor intended to be a guidance tool this possibility is not incorporated in the models which are presented.

The value of each activity is calculated in the following manner.

$$V_{ij} = \sum_{t=t_i}^{t_i+l_{ij}} (w_{ij}/(1-\rho)^t) \quad \text{where} \tag{3.2}$$

V_{ij} = value of activity A_{ij}

t_i = start time of A_{ij} = point time of E_i

if $i = 1$ then $t_i = 0$
if $i \neq 1$ then $t_i = t_h + l_{hi}$

l_{ij} = length of A_{ij}

w_{ij} = the undiscounted value of A_{ij} per period of time

ρ = personal discount rate

e = the identification number of the retirement event

$$\text{if } j = e \text{ then } l_{ij} = \gamma_R - t_i \tag{3.3}$$

$$\text{if } j \neq e \text{ then } l_{ij} = p_{ij} \text{ if } t_i + p_{ij} \leq \gamma_R; \text{ or} \tag{3.4}$$

$$l_{ij} = \gamma_R - t_i \text{ if } t_i + p_{ij} > \gamma_R \qquad \text{where} \tag{3.5}$$

$$\gamma_R = \text{number of time periods until retirement} = 12(65 - \alpha_0) - m \tag{3.6}$$

α_0 = initial age

m = number of months since last birthday

p_{ij} = time necessary to complete A_{ij}, disregarding the retirement possibility, not defined for full-time occupation activities.

The restrictions on l_{ij} in equations (3.3), (3.4) and (3.5) were necessary to force termination of the activity path at retirement age. It should also be noted that, through γ_R in equation (3.6), age is converted to the more directly applicable concept of the remaining number of time periods until retirement.

The independent variables for this calculation can be divided into activity and personal characteristics. The activity parameters are w_{ij}, which are the series of current values for the activity for each time period; p_{ij}, the time necessary to complete A_{ij}; and each activity's start and end events as identified by its i and j subscripts. The personal parameters are restricted to ρ, the personal discount rate; and α_0 and m, the person's age. It is also assumed that the individual has the capabilities as well as the interest necessary to perform any of the selected occupations. If the retirement age is reached while still in an educational activity the value of all subsequent activities is zero. Model I assumes constant payoffs, w_{ij}, in all periods for each occupation, A_{ij}.

In general, each possible path from E_1 (the start-event), to E_e (the end-event) could be identified by the designation of all event points in the path plus an additional indexing number, where more than one activity have the same event paths. This designation could take the form (1,....,z, e, a), where 1 is the start event, e is the end event, and a is the index. A path which is entering a full-time occupation without any specific education has the form, (1, e, a) with no intervening events between entry and retirement. The network of activities is continually diverging until movement to the retirement event. Because of this, the path between the start event and any other event in the network, except the end event, can be uniquely labeled by a single event number. The path from E_1 to E_b can be labeled (b, a). The 1 can be omitted because all paths are defined to start at E_1. Since all paths also end at retirement the e can be eliminated from the description of a path. The number of the first event to the left of the end event and the index are, together, sufficient to define each path uniquely. This can be written in the form P(b, a). As an example, when describing the activity path consisting of one work activity beginning at E_1 and ending at E_e the designation is P(1, a), where a = 1, 2,...,n and n is the number of different work activities originating at E_1. An occupation activity which was identified in equation 3.2 as A_{ij} is now more generally defined as A_{ija}.

Now that the value of each activity has been defined the remaining problem is to calculate the value for each path and select the maximum from these values. This is done by following the paths from right to left, in the following manner.

$$V(b, a) = \sum_{i=1}^{z} V_{x_i x_{i-1} a}, \quad \text{where} \qquad (3.7)$$

x_i = the start-event of the activity with end-event x_{i-1}

$x_0 = e$
$x_1 = b$

z = the value of i for which $x_i = 1$ (the start event)

b = the start event number for the occupational activities

$V(b,a)$ = the value of the activity path from E_1 to E_e and ending with occupational activity A_{bea}

When the values of V(b, a) are calculated for all b and a values the optimum path for educational investments is that with the maximum V(b, a).

$$V' = \text{Max } (\text{Max } V(b, a)), \quad \text{where} \qquad (3.8)$$

$$V(b', a') = V'$$

V' is the present-value attached to the optimum route. The b' and a' such that V(b', a') = V' identify those a and b values such that P(b', a') is the optimum route. The occupation defined in the optimal route is activity $A_{b'ea'}$. If the b' and a' values are not unique there exist as many optimum routes as there exist sets of b' and a' values. The present-value criteria gives no means of choosing between equal valued paths. However, the possibility of non-unique a' and b' values existing would be expected to be quite small.

2. Educational Investment Model II

Model II builds on the framework established for Model I by removing some of its restrictions.

a. Unemployment probability The first restriction dropped is that an entrant will be employable until retirement. This assumption is replaced by the assumption that there can be attached to each time period in the future a probability that the entrant will become unemployable in that period and remain unemployable until retirement age. To incorporate the unemployment probability the present-value formulation of Model I, equation 3.2, is adjusted to the following form in Model II.

$$V_{ij} = \sum_{t=t_i}^{t_i+t_{ij}} (w_{ij} u_{\alpha_0 mi} / (1 - \rho)^t) \quad \text{where} \tag{3.9}$$

$u_{\alpha_0 mi}$ = the probability of individual, age α_0 years and m months at entry still being employable in period i.

b. Zeroing backward paths In Model II the assumption that all entrants begin at the start event, E_1, is dropped. Instead, the individual for which an optimal path is determined can be at any point in the pattern of activity flows at entry. Entry now refers to the position within the network which the individual occupies at time zero, and not necessarily the event E_1. This new assumption means that anytime an individual is in the pattern of activity flows, and one or more parameters are observed to change, his occupational plans can be reevaluated to see if his optimal path has changed.

To identify the optimal path for an individual currently at any point within the activity network another change in the model is necessary. This modification is accomplished by redefining the time parameters of certain activities, prior to the calculation of their present-values. Backward movement, from right to left along any activity path is a movement along activities which have already been completed. An individual already at some point other than E_1 is qualified, without additional training, for any activities which are directly attached to the backward path of activities from his present position, E_p, to the start event, E_1. Also, the starting wage he will receive at his present occupation, if presently employed, is the wage which he is presently receiving. If presently unemployed with no prospect of re-employment in the former occupation, this wage is zero.

Free movement along backward paths is accomplished by redefining the time parameters of these activities as zero. If the entrant also has other human capital in the form of education which was not necessary for entry to his former occupation this characteristic is incorporated by redefining the time parameter of this educational parameter as zero. If this education represents an uncompleted educational program the time parameter of that educational activity should be reduced to the length of time which would be necessary to complete that activity. When these adjustments in the time parameters of activities have been completed the optimal path of educational investments can be found for an individual starting at a point along the activity network (E_p) by proceeding as if he were actually starting at E_1. This result follows because placing the time parameter of the activity path from E_p to E_1 equal to zero makes all points on this path equivalent.

With these indicated adjustments the optimum course can be determined for an individual at any point within the network of activities.

This also means that the educational investment model has the same feature as PERT in that the optimum route can be re-evaluated at any time. This is a very important feature because of the uncertain nature of the parameters of the activities.

C. Changing Model Parameters

Many types of parameter shifts might be expected to occur. Certain educational programs may take longer to complete than originally anticipated. Original projections of starting wages may be found in error. Occupations which appeared to have a promising future with adequate job openings may be found to have very limited employment possibilities caused by an excess supply of entrants for this occupation or an unanticipated decline in the demand for the occupation. New technology may create attractive new occupations for which the individual can qualify, with or without additional education. A change may occur in the personal discount rate of the individual. The individual may find that his work experience will substitute for some of the educational requirements for other jobs in the activity network with the result of shortened time parameters on educational activities which are prerequisites for those occupation activities. In the limit experience may substitute completely for education. It may also be found that an individual coming from another occupation does not start at the same wage as a person holding his first job, or as a person moving from a different job that has fewer skills transferable to the new occupation. In such a situation the entry wage of the alternative occupation is changed to this new, higher entry level. It may also be found, after being engaged in a particular occupation for a period of time, that the wages do not increase at the expected rate.

1. <u>Educational grants and loans</u>

Parameters can be shifted through the influence of government programs. A government program which pays all or part of the educational expenses for particular groups of citizens would lower the cost parameter of the included educational activities for all qualified individuals. If the program paid a stipend, in addition to all direct educational expenses, the return for the activity would increase even further. Another type of government program might provide low-cost educational loans.

The result of educational loans can be illustrated in the following manner. To indicate this effect it is necessary to separate the value of the activity, V_{ij}, which existed before the loan, the costs associated with the loan, and the new returns realized from the loan. The total value of an educational activity after a loan, V'_{ij}, is the former net current value, V_{ij}, plus the payments which must be made on the loan (negative items), plus the amount of the loan, L_{t_i}, received at time t_i. This new value, with all returns discounted to the present, is

$$V'_{ij} = V_{ij} + C_k + R_k \tag{3.10}$$

$$C_k = \sum_{t=t_k}^{T} P_t/(1+\rho)^t \tag{3.11}$$

$$R_k = \sum_{t=t_k}^{T} (L_t/(1+\rho)^t \qquad \text{where} \tag{3.12}$$

C_k = present-value of loan payments

R_k = present-value of loans

P_t = payment on the loan due in period t

L_t = loan received in period t

T = time horizon over which all loans have been repaid.

If a single loan of L_{t_i} is received in period t_i and repaid in a lump sum in period T, the total value of the education activity becomes

$$V'_{ij} = V_{ij} + L_{t_i}/(1+\rho)^{t_i} + (-L_{t_i})(1+r)^{T-t_i}/(1+\rho)^{t}$$

$$V'_{ij} = V_{ij} + L_{t_i}((1+\rho)^{T-t_i}/(1+\rho)^{T} - (1+r)^{T-t_i}/(1+\rho)^{T})$$

$$V'_{ij} = V_{ij} + L_{t_i}((1+\rho)^{T-t_i} - (1+r)^{T-t_i})/(1+\rho)^{T} \qquad (3.13)$$

If r, the interest rate on the loan, is less than the personal discount rate, ρ, it can be seen that the result is to increase the value of the education activity. (The implicit assumption that the loan had no effect on the personal discount rate, has been made.) Any combination of loans and methods of repayment will give the same result, that the total value of the education activity is increased if the personal discount rate is greater than the interest rate on the loan. This result is easily conceptualized if one views any loan as divisible into any number of smaller loans, of which one is paid each time a loan payment is made. The same approach can be made to loans which are made at different times throughout the educational activity. These loans can be viewed as being paid one at a time as the payments are made. Each loan then makes a positive addition to the activity's present-value.

The importance of loans in stimulating educational investment was considered in Chapter II, Part A, and will be considered in the following chapters of this report.

2. Social values

A different set of parameters can be applied, by changing the basis for valuation from individual returns to social returns. The model can then be used to point out the mix of formal and vocational education, and the final occupation which the individual should enter to make his decision socially optimal.

At this time it is necessary to point out that certain problems are inherent with the use of social valuations in education and occupation activities. Many problems arise when any attempt at social valuation is made. Other problems are specific to the use of social values in this specific model.

In welfare economics there exists a large body of literature concerning establishment of a social welfare function. The social welfare function specifies the relative values which should be placed on each item in the economy. The conclusion of the literature is that only under the most strict conditions can a social welfare function be defined at all (5, pp. 22-33). These restrictions are so strong that they make the use of any such function unrealistic. Thus, an operational social welfare function is based on subjectivity and not on application of specific objective analytic procedures based on generally accepted premises.

While it is not possible to define a specific, generally accepted, social welfare function, it is possible to place values on particular items which approximate generally accepted criteria for social valuation. In education the social cost of education might be measured as the expenditures on the inputs to the educational process. In the situations where individuals consuming the education do not pay the total cost of the education there exists a definite difference between the social cost of the educational process and an individual's costs. The same can be said for the returns from education. Whenever there are returns from the educational process that do not accrue to the individual receiving the education (i.e. positive externalities) social returns can be said to be greater than individual returns.

When dealing with social values it is more useful to speak of these values within the context of the entire economy. When measuring the social value of a particular worker in a particular occupation, it should also be considered what would be the value of a different worker in that same job and what would be the output of that worker in alternative forms of work. When occupations considered are those which currently have numerous job openings it is not as necessary to consider the social value of another person in the same position because the second person can also enter the occupation and openings will still remain. In a situation with numerous job openings, it is easier to apply a social value to the actions of a single individual because then the individual's actions only are considered and the relationship of his actions to others can be more easily disregarded. This is the situation when social values are substituted for individual values in the educational investment model just presented.

The replacement of individual costs and returns with social costs and returns in the educational investment model, given the necessary reservations, identifies the socially optimal path of educational activities and final employment for the individual to follow. When the maximizing actions of an individual are compared to the socially optimal actions of the same individual, within the structure of the model, it can be seen if they are the same or tend to diverge. If the latter is the case changes in individual parameters can be considered to identify a situation where the individual will choose the socially optimal path or, at least, a more socially desirable route. The principal tools for this parameter adjustment would likely be educational loans and stipends, as previously discussed. The educational loan and/or grant necessary to move a certain individual toward the socially optimal decisions can then be found. Of course there is not a single policy, but rather a number of policies to achieve the same ends.

D. The Applied Model

The applied model was in the form of a Fortran computer program. A skeleton version of this program is shown in Figure 3.5 and a more complete version in Figure 3.6. In Figure 3.5 the first operation represents the zeroing of the times for all activities which are linked in a backward path from the individual's present position in the activity net-

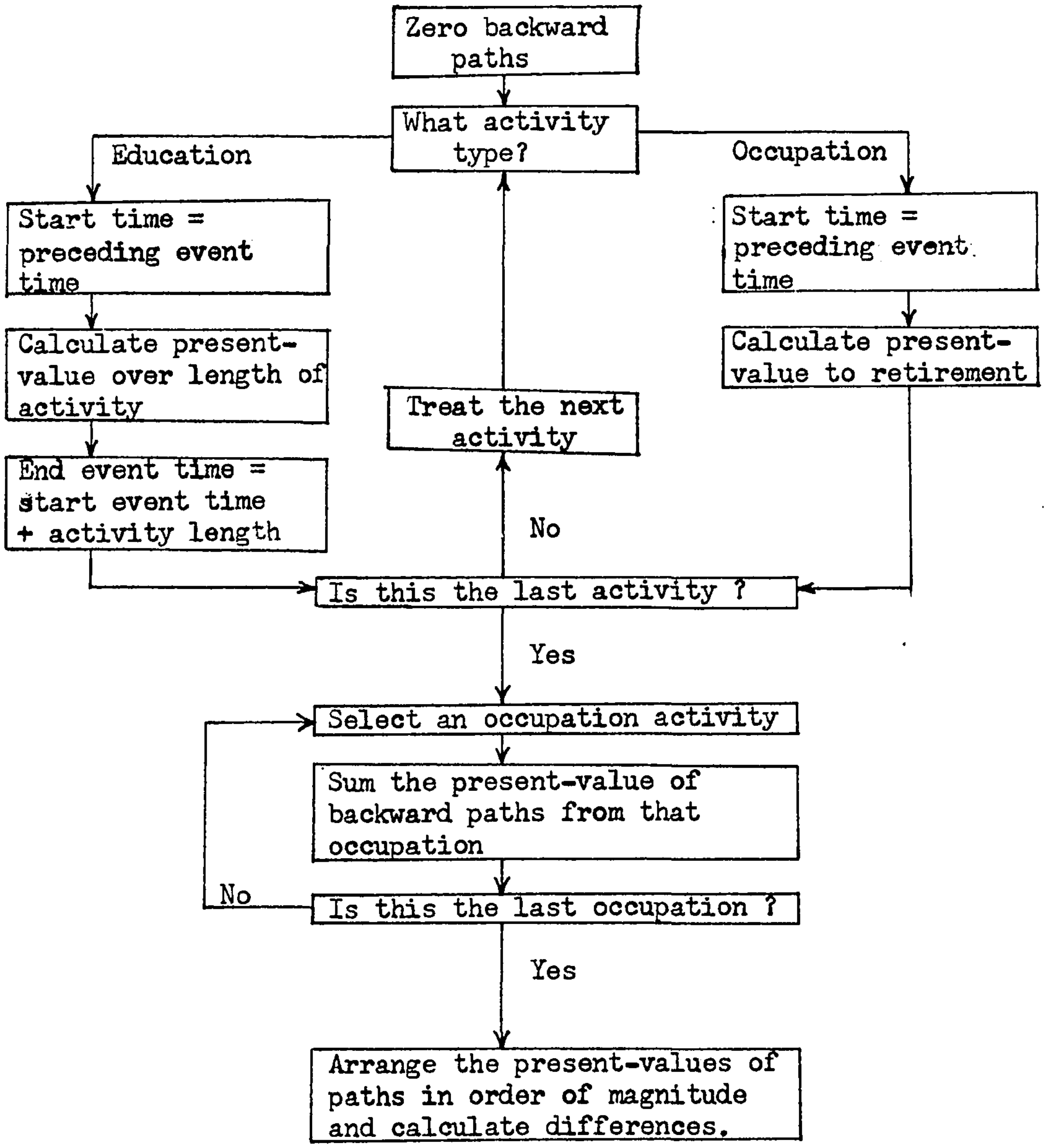


Figure 3.5. Simplified operational model

work to the beginning activity of the network. This allows the person to reach, at zero cost, any activities for which the individual has already fulfilled the prerequisites. This step also includes the adjustment of the present occupation's payoffs, if the person is currently employed. The next step is to calculate the present-values of all activities. Present-values of occupation activities were calculated from the start-time to the start-time plus the length of the activity. This end-time was identified as the time of the activity's end event. Activities having this event as a start-event then had this event time as their start-time. This procedure necessitated that activities be treated in their order of occurrence in the network. Therefore, the start time of activities was identified by the sum of the times of backward activities.

The numbers in Figure 3.5 correspond approximately to the same numbers on the steps of Figure 3.6. Figure 3.6 presents more detail of the exact procedure of the operational model than does Figure 3.5. Also, some projections and estimations which were omitted from Figure 3.5 are included in Figure 3.6. An example of an omission from Figure 3.5 is the first operation of Figure 3.6, which is the calculation of all basic wages, by the general education category (I), and the time in employment (J).

When the present-values were calculated for all activities, these values were summed over each path from the beginning to the end of the network. There is a one-to-one correspondence for these paths and the occupation activities. For this reason each path was identified by its

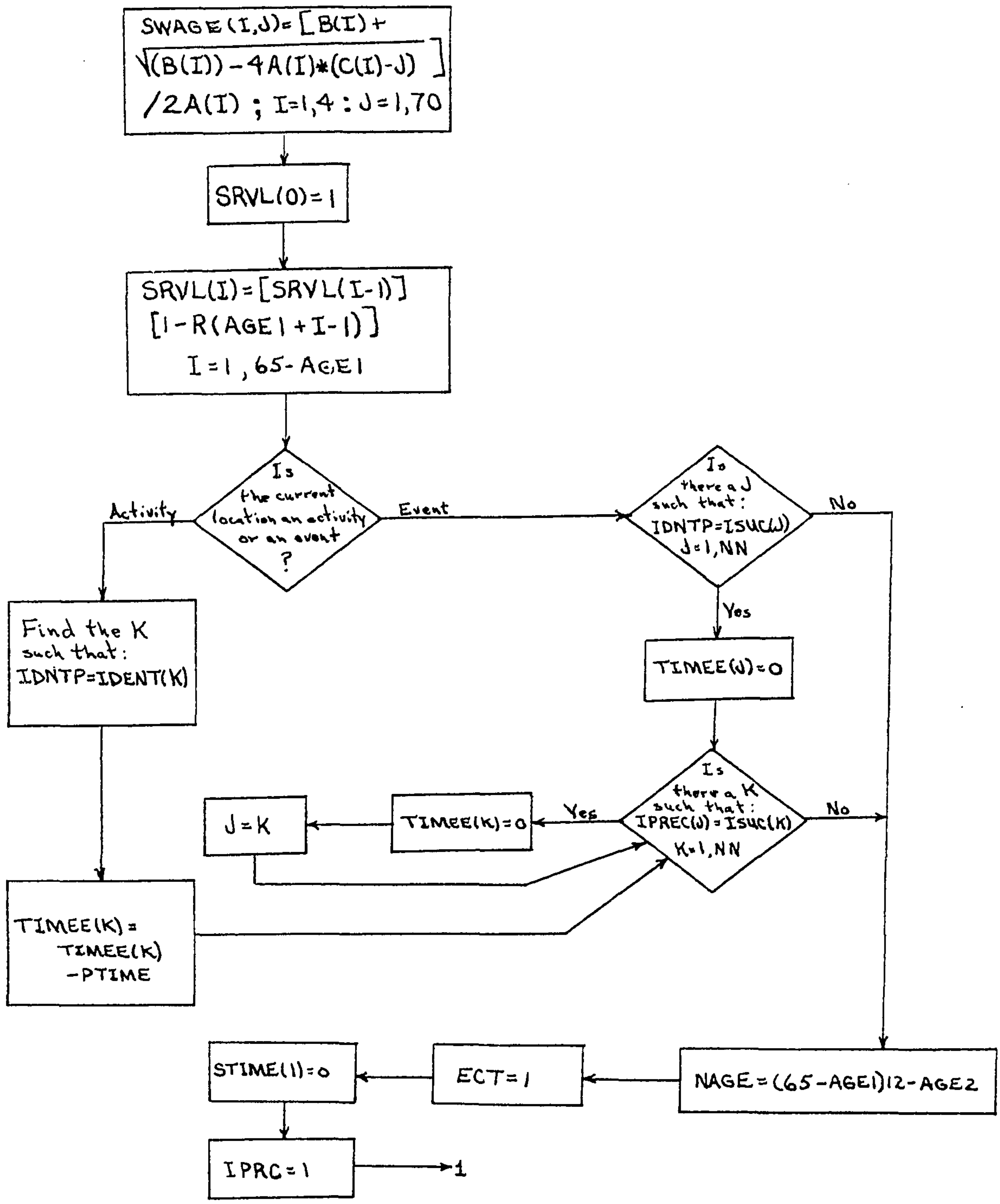


Figure 3.6. Generalized flow chart of operational model

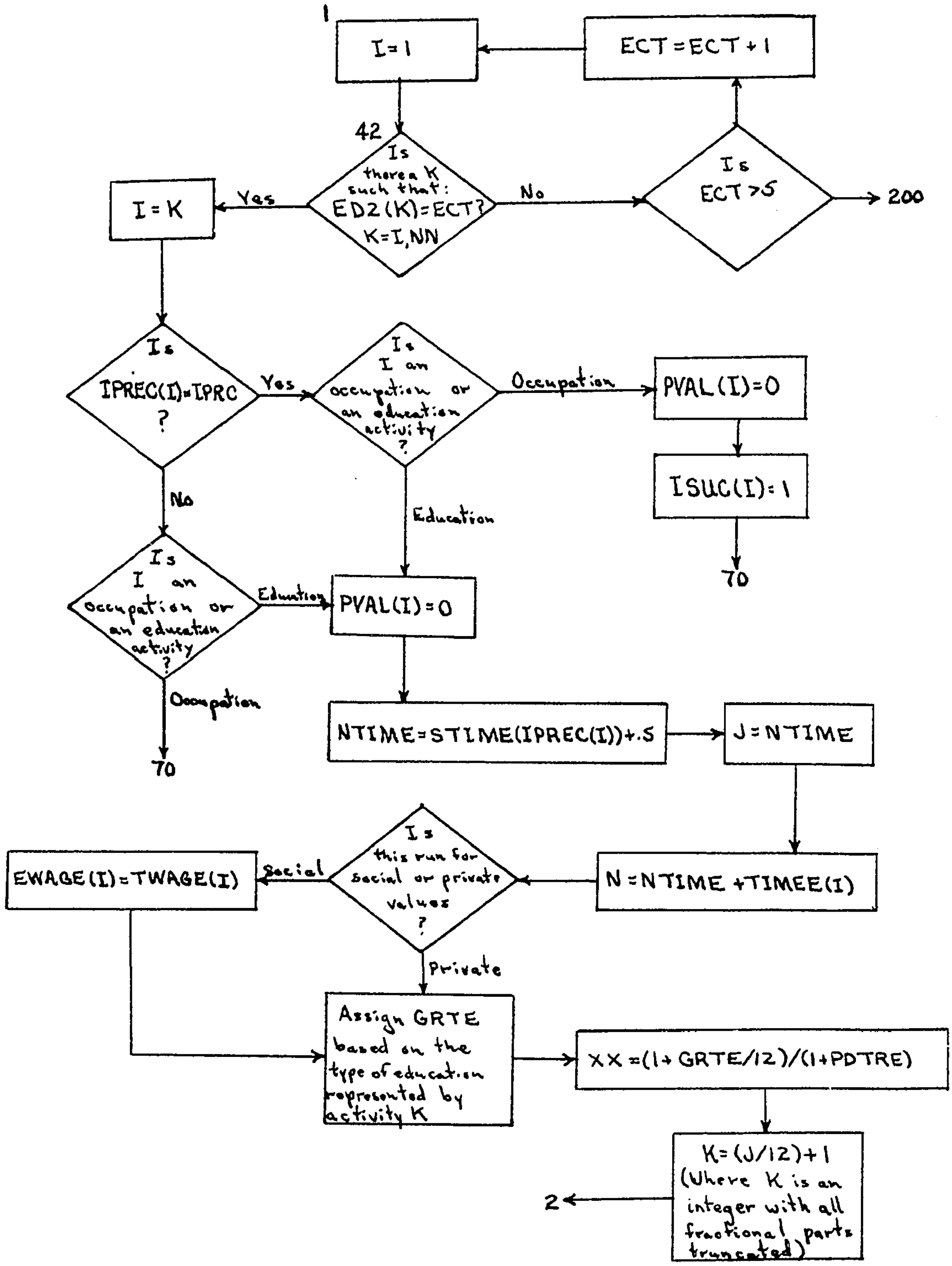


Figure 3.6. (Continued)

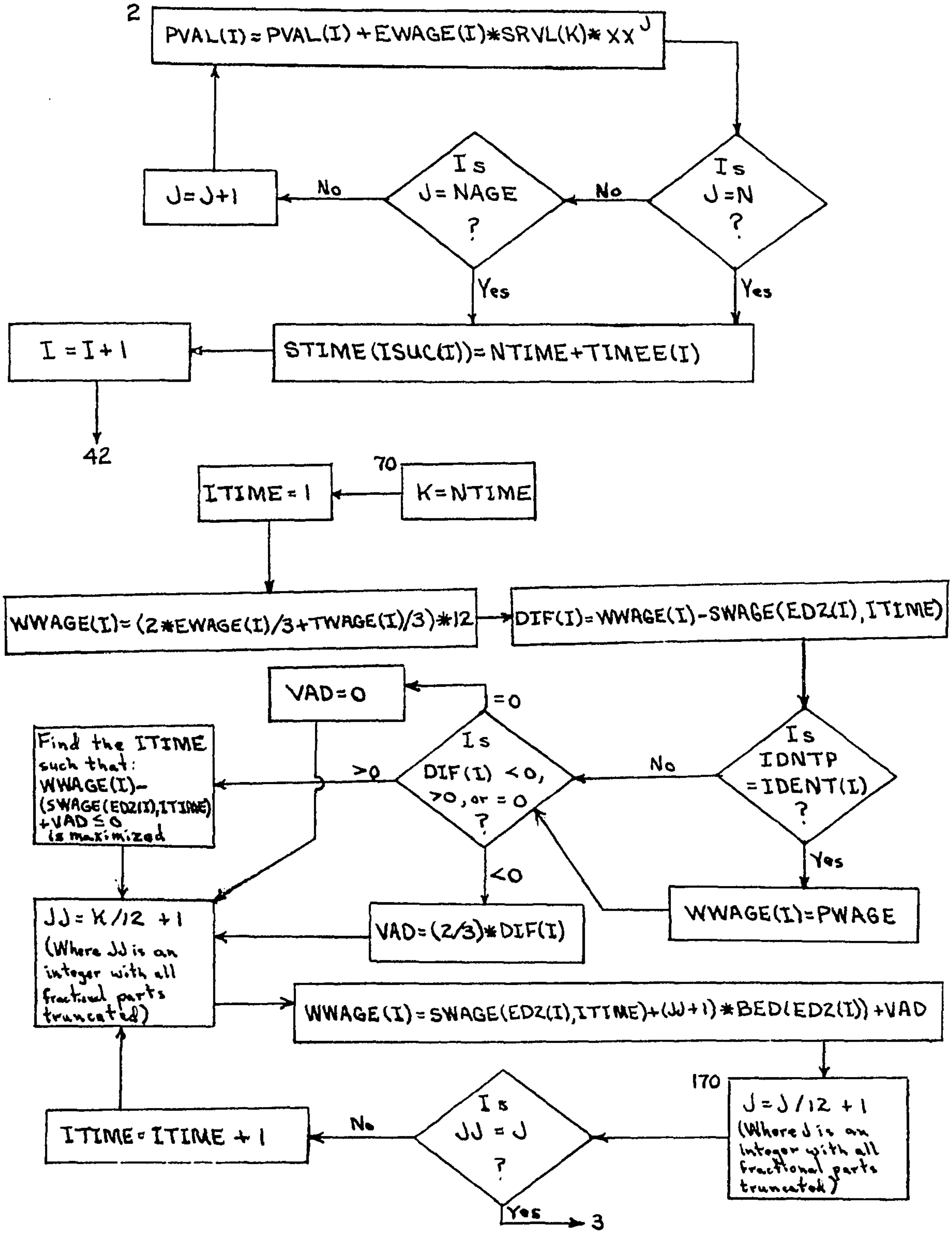


Figure 3.6. (Continued)

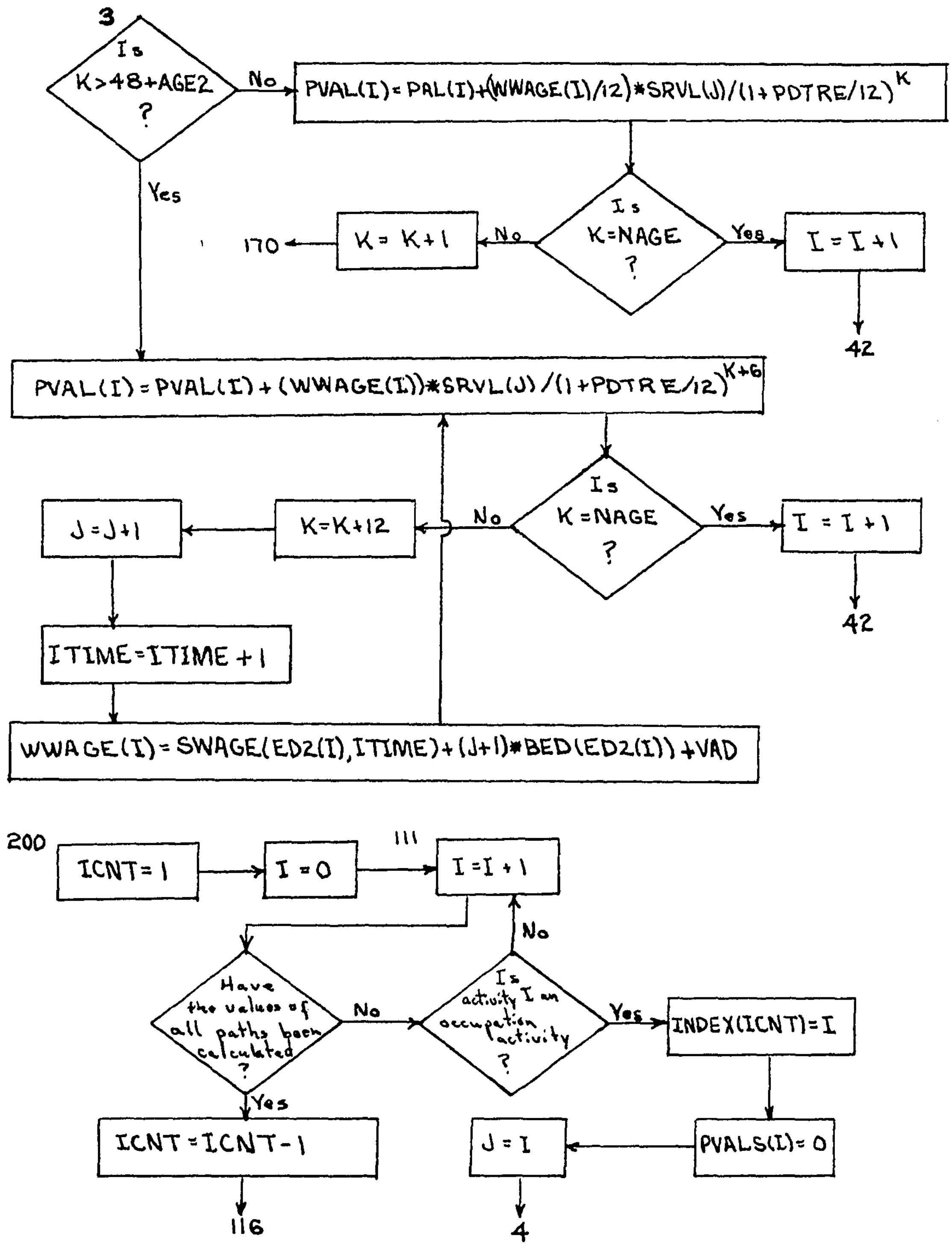
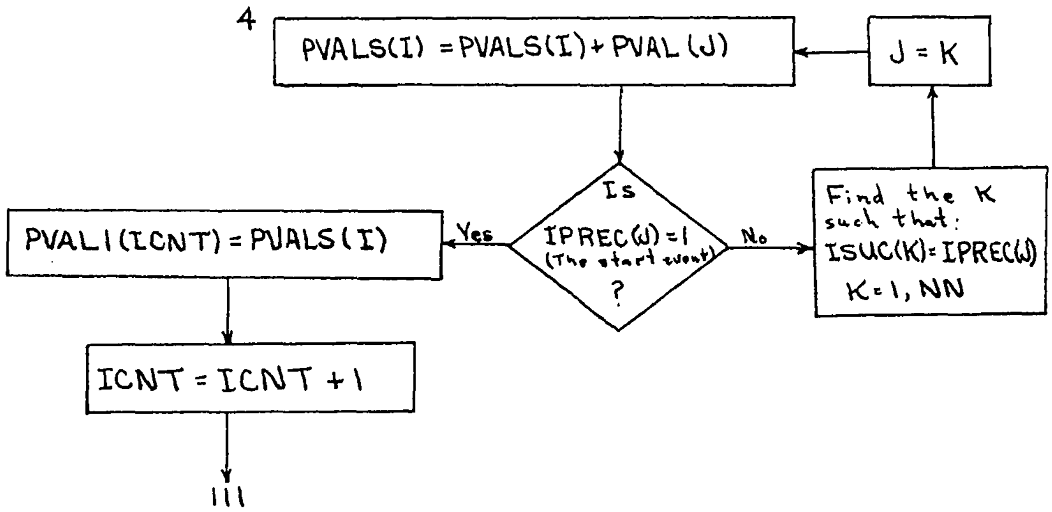


Figure 3.6. (Continued)



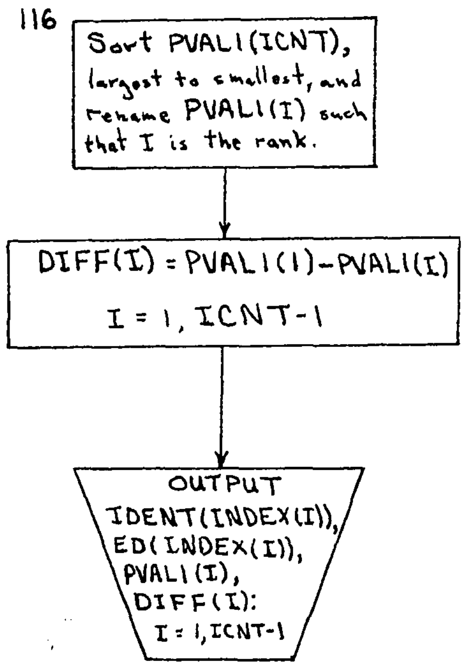


Figure 3.6. (Continued)

final activity. When all activity paths were identified and their present-values calculated, these values were arranged in order. Next, the differences between each activity and the activity with the largest present-value were calculated. The discussion of estimating activity parameters, in Chapter IV, deals in detail with the method of placing actual present-values on each of the activities.

Table 3.1. Description of selected parameters used in the generalized flow chart of the model

Name	Description
ED	Entrant's current level of general education
VT	Entrant's current level of vocational education
IDNTP	Entrant's present location in the activity network
AS	Is the entrant presently in an activity (0), or at an event (1)
TA	If presently in an activity is it education (1), or an occupation (3)
PTIME	If presently in an activity how long has it been since entry
AGE1	Entrant's age in years (integer rounded to the low side)
AGE2	Additional months of entrant's age, over the years of AGE1
PWAGE	If currently in an occupation, the wage being received
IPS	Are social values, private values, or both desired
IPREC(I)	Identification number of the event preceding activity I
ISUC(I)	Identification number of the event succeeding activity I
EWAGE(I)	Entry wage for activity I, if I is an occupation activity Private cost for activity I, if I is an education activity
TWAGE(I)	Top wage for activity I, if I is an occupation activity Social cost for activity I, if I is an education activity
TIMEE(I)	Length (in months) of activity I, if an education activity
ED2(I)	Level of general education required to enter activity I
VT2	Months of vocational education necessary to enter activity I
IDENT(I)	Identification number of activity I
TA2(I)	Is activity I education (1), or an occupation (3)
SWAGE(I,J)	Basic monthly wage projection for educational level I and year J

Table 3.1. (Continued)

Name	Description
A(I),B(I), and C(I)	Parameters of the wage parabola for educational level I
BED(I)	Annual wage increase of a given job, with general education prerequisite I
R(I)	Mortality rate for age I
SRVL(I)	Probability of surviving to the end of year I
NN	Number of activities
STIME(I)	Number of time periods in the future activity I will start
GRTE	Growth rate of educational costs, assigned according to the particular educational activity
NAGE	Number of months remaining until retirement at age 65
ECT	Switching operator for level of education
IPRC	Switching operator for checking the preceeding event
PVAL(I)	Present-value of activity I
STIME(I)	Time at which event I occurs
ITIME	Number of yearly periods distant from entry
WWAGE(I)	Weighted and adjusted starting wage for occupation I
ICNT	Counter for number of activity paths
PVALS(I)	Present-value of the activity path ending in occupation I
INDEX(J)	Correspondence between an occupation activity and activity path J
PVAL1(I)	Present-value of activity path I
DIFF(I)	Difference between the values of the activities ranked I and 1

IV. MODEL APPLICATION

A. Application to Survey Information

To make the educational investment model operational, it was necessary to have data of a very detailed nature. The necessary type of information (giving a large number of characteristics for quite narrow occupational categories) was available from a survey of the metal-trades industries in Iowa. Thus, for the results reported here to be most meaningful, the results of any optimal path analysis herein should be applied only to individuals who have a strong preference for the occupations in the sampled group and employment in Iowa. Under the assumption that payoffs within each group are characteristic of the entire nation, the restriction to employment only in Iowa can be dropped.

1. Survey description

This survey, conducted at Iowa State University under a grant from the Office of Education, U.S. Department of Health, Education, and Welfare (81), had a two-fold objective. The first objective was to collect occupational information on job vacancies by using sampling techniques. The second objective was to develop skill cluster classifications for occupations.

In fulfillment of the first objective, a sampling technique was devised for the collection of occupational data. The population of firms was defined to be all Iowa firms in Standard Industrial Classifications (SIC's) 33, 34, and 35. These categories are: SIC 33, primary metal industries; SIC 34, metal fabrication, excepting ordinance; and SIC 35, machinery, excepting electrical. Information on the actual firms composing these categories and the number of employees in each firm, was obtained from data supplied by the Iowa Development Commission. Firms were placed in size categories according to number of employees and within each category were arranged by the third and fourth digits of their Standard Industrial Classification. These second two digits indicate a more specific definition of the industry than do the first two digits. Firms in the size groups of 100 or less were sampled systematically. Firms with total employment of more than 100 were all included in the sample. This sampling and the subsequent interviewing was conducted by the Education Department and the Statistical Laboratory at Iowa State University.

The survey was implemented by the use of experienced interviewers making personal contacts with the appropriate individuals in the sampled firms. The interviewers asked questions related to two basic types of data. The first type of data, which composed by far the smallest part of each interview, concerned the present and expected levels of employment for the entire firm. The second type of collected data related to specific occupations within the firm. The interviewers were provided lists of occupations which might be expected to occur in each firm. In total seventy different metal-trade occupations were covered by the survey. The definitions for these classifications were taken from The Dictionary of Occupational Titles, Third Edition (89). These definitions from the Dictionary of Occupational Titles (called DOT hereafter) were accompanied by numerical indexes, which were used for occupational designation in the survey, and which are also used in this study.

The respondents for the firms were asked the present level of employment in each of the occupations, and the level of employment which they expected one year, and three years, hence. They were also asked if there were any current job vacancies and whether they found the occupation hard to fill. Respondents were also asked the academic education requirement for job entry. Possible responses to this question were (1) college degree, (2) some college, (3) high school diploma, (4) some high school, (5) eighth grade or less, or (6) don't know. A question was asked about the specific occupational training requirements for job entry. Possible responses were (1) none, (2) vocational training school, (3) previous work experience, (4) vocational training school and previous work experience, and (5) vocational training school or previous work experience. If the response to the question on specific occupational training requirements for job entry was either (2), (4), or (5) the usual length of training time in the vocational skill (i.e. vocational training school) was asked. The possible responses to this question were, (1) less than 6 months, (2) 6-12 months, (3) 12-18 months, (4) 18-24 months, (5) more than 24 months, and (6) don't know. These questions were asked to allow the differentiation of occupations with the same D.O.T. classification into several different occupations, by the levels of education required for job entry.

Other information from the survey which is used in this study is on the payoff expected from each occupation, as differentiated by D.O.T.

number and levels of education required for job entry. The two questions relating to wage rates were the beginning pay rate and the top pay rate. A third question on the time period to which this payoff applied allowed the adjustment of hourly, weekly, and monthly pay periods to common time periods.

2. Survey limitations

While the survey supplies information directly applicable to the model there are some definite weaknesses and limitations which should be pointed out. While some of these problems arise from the survey, itself, others appear only when the survey data is applied to this particular model.

In some occupation[1] categories sample size could become a problem. The problem referred to arises from a small number of firms employing individuals in the particular category and not from the total number of employees which were indicated over all firms.

As with any survey information gathered through interviews there are possible problems with the meaning and validity of responses. Was the correct question asked? If the correct question was asked and interpreted correctly did the respondent have adequate information to correctly answer? There is no simple way to check for types of errors just suggested. It can be hoped that by requiring an adequate sample

[1]Occupation refers to a category differentiated by its unique combination of DOT number and general (i.e. academic) and vocational education requirements for job entry.

size for all the estimates made, such errors will either offset each other, or will become insignificant, since their frequency of occurrence is small.

The model's limitation in drawing conclusions arises from limited data, as has already been specified. Within its limited nature application of this model to the Iowa metal-trades situation remains meaningful.

3. Fitting survey data to the model

To justify the use of the Iowa survey data with the educational model it must be shown that wage expectations for metal-trades are positively influenced by both general and vocational education. To test this hypothesis multiple-regression analyses were run with beginning hourly pay rates and top hourly pay rates as dependent variables and levels of education as independent variables. These regressions are presented in Appendix A.

In these regressions prerequisite education consisted of four levels of formal education, five levels of vocational education, and previous experience. These educational prerequisites were used as the independent variables. All independent variables were represented as one-zero dummy variables. In Table A. 2 and Table A.4 the F-ratios show that in both cases the linear regressions explain a significant amount of the variation of both starting and top wages in these Iowa data. These results indicate the appropriateness of using these Iowa data in a model based on the hypothesis that education can be viewed as an investment leading to increased rates of payoff on the job.

Any data applied to the model had to meet the two criteria of validity and usefulness. Validity refers to the accuracy of the data and is determined by the number of firms sampled in each category, as already mentioned. Of course the number of observations has to be teamed with the variability of the population before the validity of an estimator can be tested. The usefulness criterion, a more nebulous concept than validity, simply put answers whether or not a particular occupation is important enough to consider.

For the model presently in use this would depend on the total number of employees in the occupation, the expected growth-rate for the occupation, institutional constraints to job entry, personal interests and aptitudes, and a number of other possible items. The usefulness criterion can be reduced to a problem of size, as was the validity criterion. The size problem now is whether the number of job possibilities is sufficient to make consideration of employment in the occupation worthwhile for the entrant.

Occupation categories must be defined broadly enough to satisfy the validity and usefulness criteria. Identification of occupational categories by the reasonably fine divisions of the survey gave many occupational groups which did not meet both of these criteria. The first division of the Iowa data was on formal education required for job entry. This division was followed by a division by 4-digit DOT classifications within the formal education groups. Finally, these two groups were further sub-divided by a grouping indicating the amount of vocational training needed for job entry. The vocational training categories were:

(1) none, (2) less than 6 months, (3) 6-12 months, (4) 12-18 months, (5) 18-24 months, and (6) more than 24 months. Since general but not exact vocational training requirements were identified within each of these broad categories, placing an exact requirement, in terms of months of vocational training necessary for job entry, had already become a procedure subject to unavoidable errors. Thus, rather than estimating variances of wages in each occupational category and then defining each category so that estimates were within given probability limits, a general rule was applied to all occupational categories. Aggregations of groups were then made until categories were broad enough for analysis.

It was decided to make the minimum employment size of each occupation 100 employees. The minimum number of observations (i.e. sample firms included in the category) was ten. In the aggregated occupation groups both of these limits were generally exceeded.

The following steps were taken in proceeding with the aggregations. No aggregations were made between levels of formal education or DOT classifications. All aggregations were done through the combination of vocational training for job entry groups, within the other two classifications. Wage figures for the new groups were averages of the wage estimates for the groups being aggregated. These new wage estimates were averages weighted by the relative levels of employment in the original groups. The length of vocational training time parameters for the new occupations were weighted averages of the mean time of each of the vocational training categories for the old groups. Weights were placed by the relative level of employment, as in the wage rate case. These weightings put all figures on an average per employee basis. The last vocational training group, "more than 24 months," which has no mean since it has an undefined upper bound, was given a value of 30 months for use in the aggregations.

4. Linkages of operational model activities and events

Figures 4.1 through 4.4 represent the linkages of the activities in the operational model. The four figures are meant to represent a continuum of activity linkages with each figure representing a continuation of the preceding figure. Activities are represented by arrows and are always both preceded and succeeded by events. Events are represented by circles. Arrows which have no end-event represented are occupation activities which have retirement, 999, as their end event.

Numbers along the arrows represent the identification numbers of those activities. Numbers appearing in the circles represent the identification numbers of those events. All education activities begin with nine. General education activities begin with 90, and vocational education activities begin with 91, 92, 93, or 94. The rectangles are only a convenient extension of their enclosed events.

The identification number of an occupation activity generally corresponds to its DOT classification. Such a number may be repeated from one figure to another; therefore the maximum level of general education required for entry, as well as the full identification number, is necessary for unique activity identification. When more than one level of the occupation activity occurs at the same general education category an additional digit is added to the end of the DOT classification. A

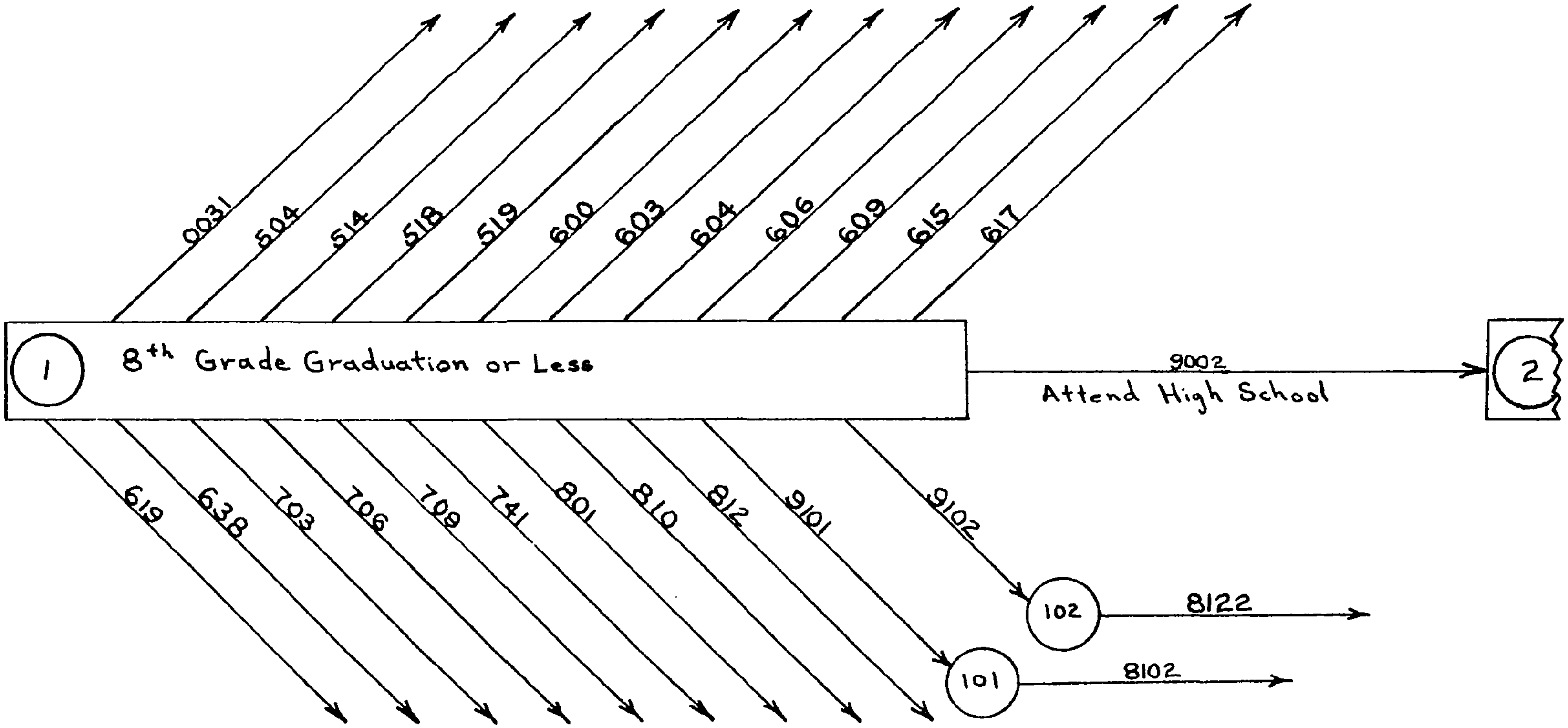


Figure 4.1. Event and activity linkages, eighth grade or less

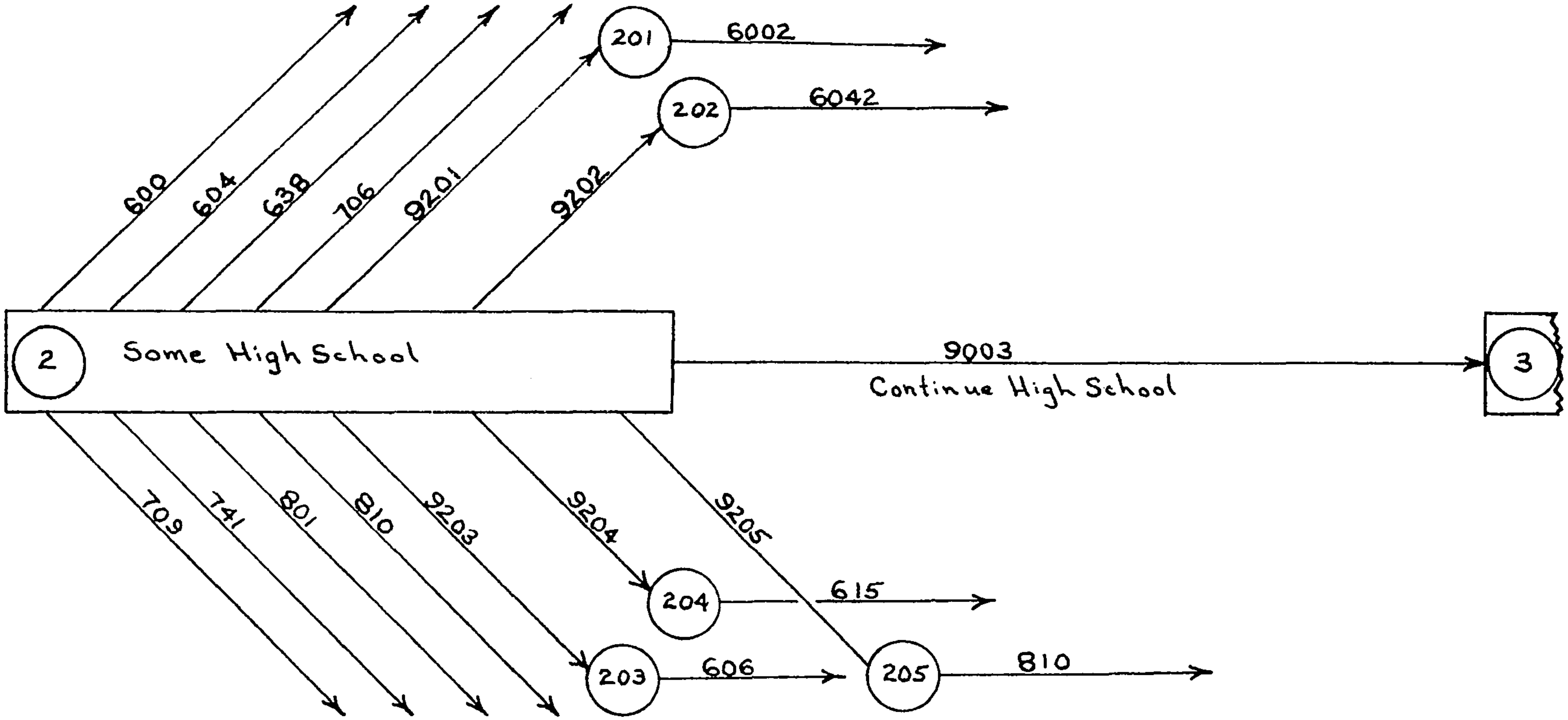


Figure 4.2. Event and activity linkages, some high school

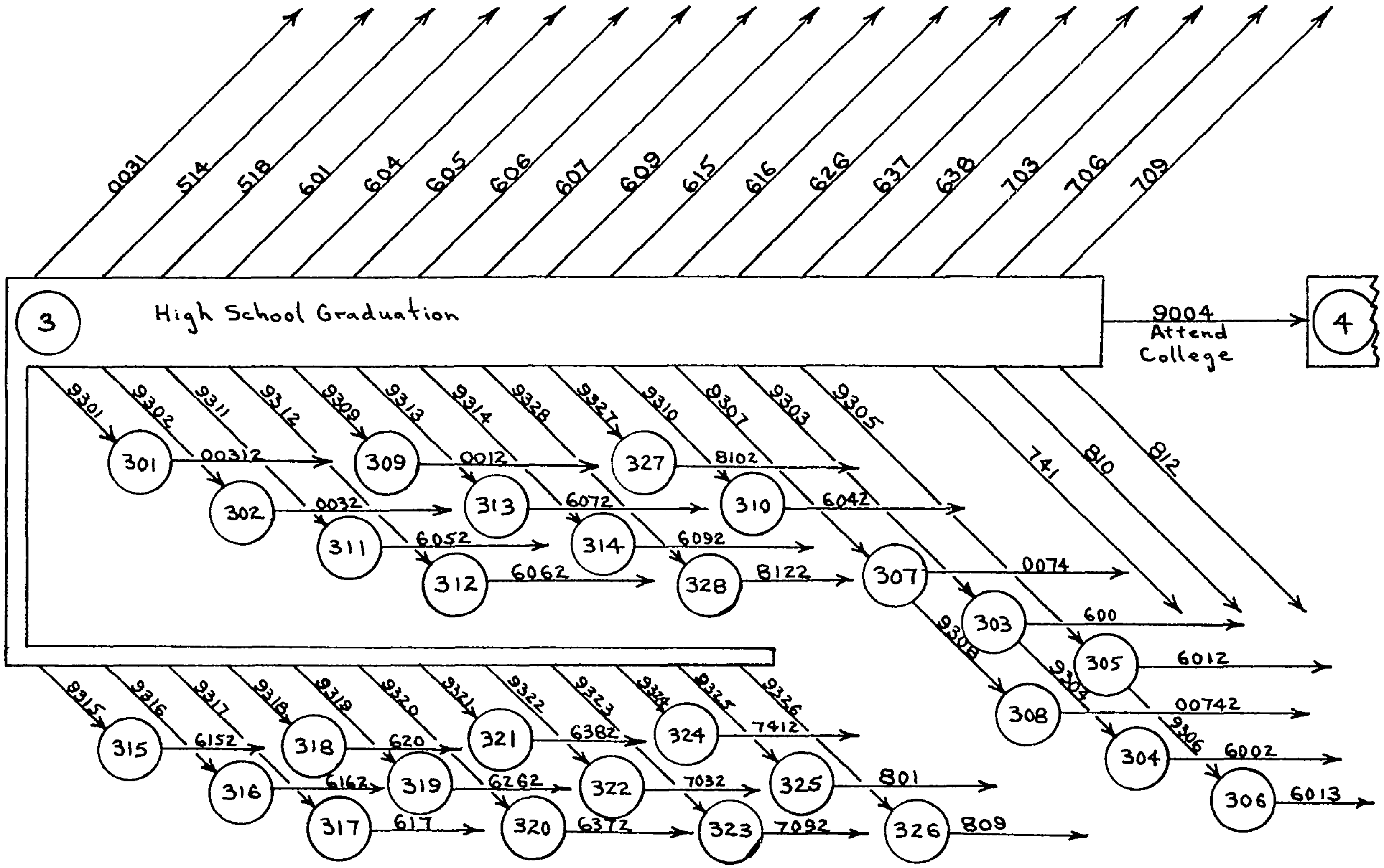


Figure 4.3. Event and activity linkages, high school graduation

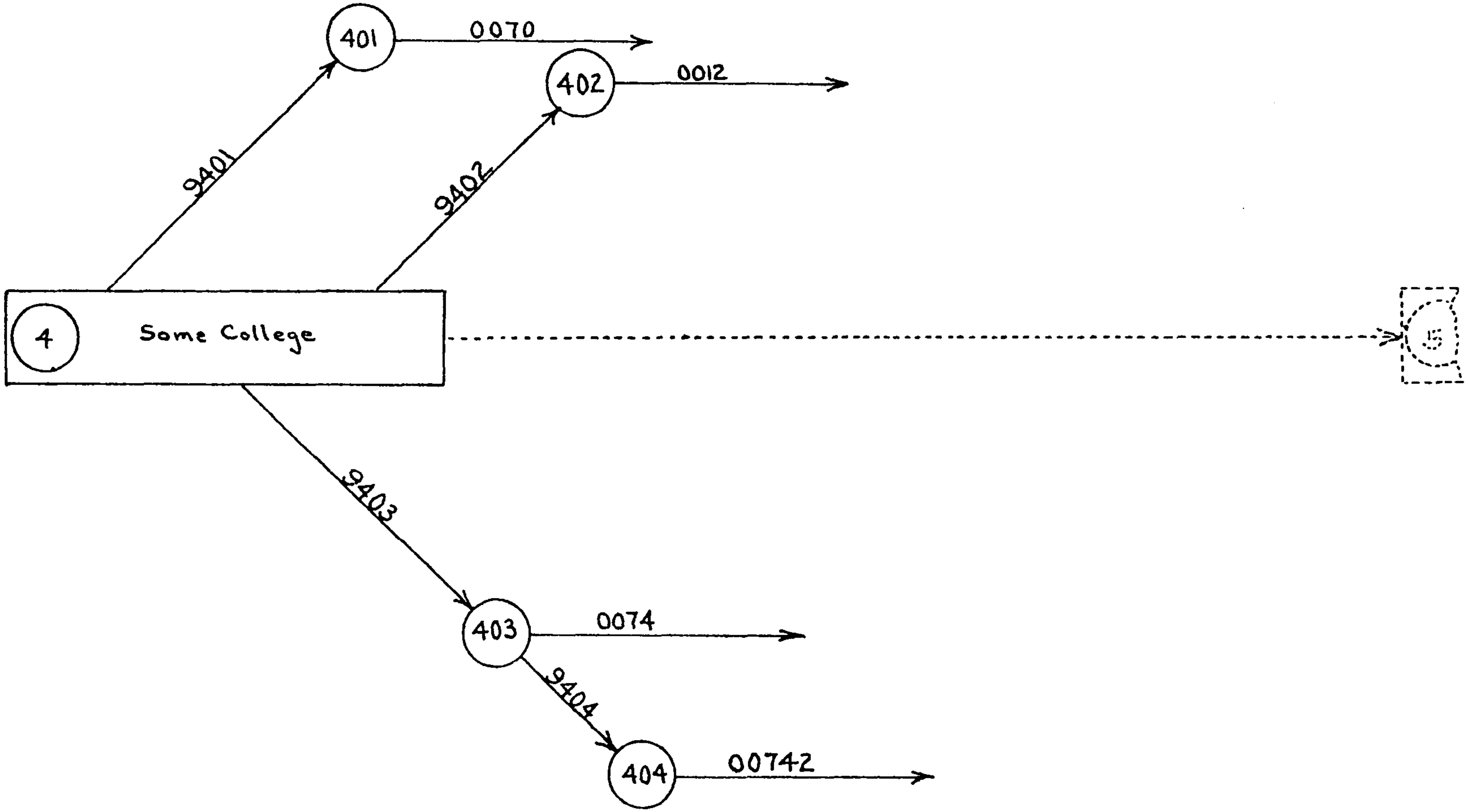


Figure 4.4. Event and activity linkages, some college

second level is designated by the addition of a two, a third level by a three, etc.

After aggregations were made, those occupational activities which met the two criteria of validity and usefulness were selected. The remaining occupational activities were fitted into a flow of activities. The occupational activities were linked to their educational prerequisites, with events marking the activity linkages. The occupational categories specified became the occupational activities of the operational model. The general education and vocational training requirements for entry completed the specification of linkages necessary to define all activity linkages. Appendix B presents a specific description of each of the occupations and of the five general occupational categories from which they come.

B. Estimation of Activity Parameters

Requirements of the model necessitated the use of data sources in addition to the Iowa metal-trades survey. As indicated earlier, the wage information from the Iowa metal-trades survey, was not adequate to project wages over a lifetime. Values for education activities had to be estimated apart from the survey in both private and social terms. Projections of wage values had to be made to cover a wage earner's income over his lifetime. The probability of receiving income in future periods also had to be considered. Since the model applies to value over a productive life, reaching to retirement, all parameters based on current information had to be projected to future expected values.

1. General education activity parameters

An education activity might commonly be thought to have a current negative return. It should be realized that the education activity, as treated in this model, encompasses all of an individual's time while enrolled in a full-time curriculum and does not explicitly include opportunities forgone. The net return to the activity is the sum of expenses from the activity and the income earned during the time of the activity. The actual educational program may not fill the person's day and may include vacation periods. Within the structure of the model even the three-month summer vacation is considered as part of the education activity. Thus, income earned by part-time employment during such breaks in the educational program becomes a return to the educational activity.

The value of an educational activity should be defined so that it is consistent with the value of occupational activities. Income for an employed worker, in excess of that received from his regular occupation, was not considered a return to that occupational activity. That is, earned income derived from sacrificing leisure in excess of the amount commonly sacrificed by persons in the same major activity, was not income to that activity for uses of the applied model. Such income was considered a transformation of nonmoney leisure income into money income. Consistency required that students be treated in the same manner.

a. Current private value of high school education It was estimated that private costs of $100 per year were directly attributable to high school education. These private costs represented expenditures on such items as books, special clothing, school related fees, and added transportation expenses. Only costs in addition to those incurred by a person choosing not to enter high school, are included. In addition a high school student was expected to earn some money during the summer months (32). It was estimated that students in their first two years of high school would have $200, and those in the last two years $400, in summer earnings. This yielded a net annual return of $100 for the first two years and $300 for the second two years. The net return was projected to increase by four percent per year.

b. Current social value of high school education Data on the direct social costs of secondary and primary education in Iowa were obtained from the Iowa Department of Public Instruction's annual publications titled, Iowa Public School Data (41, 42). Since the 1962-63 school year this publication has not separated the state total per-student-cost by level of education, but has given only one cost figure for all grades, through twelfth grade. Before that year, state averages were separated into elementary and high school averages. The Iowa Board of Public Instruction was able to supply a cost estimate for the 1966-67 year, separated by elementary, junior high, and high school categories. These per-pupil-costs were: elementary, $465.54; junior high, $589.41; and senior high, $655.32.[1] These values compare with an overall average cost of $567.63, for the same period.

---

[1] Bechtel, Dave, State Board of Public Instruction, Des Moines, Iowa. Iowa public education cost data. Personal communication. 1968.

Data on the overall average per-student-cost for the school years from 1958-59 to 1967-68 (1963-64 and 1965-66 data were not available) were run as the dependent variables with the school period as the independent variable. The 1958-59 year was used as the base year, with a value of one. Experimental fitting of these data to linear, semi-logarithmic, and full-logarithmic functions indicated that the best fit was obtained with the simple linear regression. The slope coefficient of 32.51 was significant at the .99 level, having a t-value of 10.6693 with six degrees of freedom. The predictive equation was:

$$Y = 275.38 + 32.51\ X. \tag{4.1}$$

The educational investment model requires data on the cost of high school education but not on the cost of elementary or junior high programs. To meet this requirement the estimates of overall per-pupil-cost were adjusted to estimates of high school per-pupil-cost. This was done by assuming that the ratio of high school costs to overall costs which held in 1966-67 will hold in future periods. This ratio of 655.32 divided by 567.63, or 1.15448, was multiplied by the slope coefficient of the previous equation, giving a new slope coefficient of 37.53. With this adjusted slope and assuming 1966-67 as the base year, or period zero, the new estimation equation for social costs of high school education is: $Y = 655.32 + 37.53\ X.$ (4.2)

The year 1967 was used to initialize the estimates of all parameters. Thus, on the 1967 base which is school year 1967-68 as year one, the equation remains the same as given above. This means a cost of $692.85 the first year and an increment of $37.53 for each additional year.

To this cost figure, which is a negative return, must be added the positive annual returns from summer employment of $200 and $400. Thus the net annual social returns are negative $455 for the first two years and negative $255 for the last two years of high school. These summer returns were projected to increase by four percent per year.

c. Current value of college education It was difficult to arrive at a single private cost figure for college education. Clearly college education is a fairly highly differentiated product. The willingness of an individual to pay higher tuition and fees may reflect many items including a higher quality program in his chosen curriculum, or consumption expenditures. Consumption expenditures may be made for reasons of prestige, parental ties to the university, a better party life, true intellectual pursuits, or other items, both real and imagined. Since the model treats individuals entering metal trades and college graduation is not a prerequisite for any occupations treated in the model, it was assumed that the college education program is of a low cost type, such as a junior college. Under this assumption private educational expenditures were estimated at $900. Individual returns from summer employment were also estimated at $900 leaving a net college cost of zero. This net current value was projected to remain at zero.

Social costs of the first two years of college education were taken from Cage's study which showed an average annual cost of $1,002 for arts and science transfer curricula in Iowa area schools (18, p. 7). This figure plus the summer earnings of $900 left a net annual social value of negative $102 for college education. This figure was projected to increase at six percent per year.

2. Vocational education activity parameters

a. Current private value of vocational education General education activities consist about three-fourths of time spent in the education process and one-fourth of time spent in vacation periods where participants can engage in work yielding a positive return. Vocational education activities include no such vacation periods, running continuously from entry to completion. This results in part of the higher cost estimate for those engaged in such activities with this cost estimated at $1500 per year (20). Also, tuition costs may be higher and there may be some additional expenses in shop courses. As with the private cost of college education the correct cost to use ultimately becomes a matter of judgement. These private costs were projected to increase at four percent per year.

b. Current social value of vocational education The data used for the social costs of vocational education programs were from a study of the costs of programs in Iowa area schools, by Cage (19). The Iowa area schools consisted of four area vocational schools and eleven area community colleges. The area schools varied widely in their course offerings, both in what programs were offered and, for vocational programs, in the length of these programs.

The cost data used here are from programs in 1) electronics technology; 2) mechanical drawing; 3) mechanical technology; 4) refrigeration, heating, and air-conditioning service; and 5) welding. Cage's study covered a total of fourteen vocational-technical programs. Costs included all expenditures except initial expenditures on equipment and plant. Included in the costs were both fixed costs for establishing a curriculum and an assigned portion of the school's operational costs, not directly assignable to any particular course or program. Results of the Cage study showed that vocational-technical programs had significantly higher costs than the arts and science transfer curriculum, which were also offered in the area community colleges. It was also found that costs for similar programs differed significantly among the area schools.

A multiple regression analysis was run on data from Cage's thesis with the results shown in Table 4.1 and Table 4.2.

Table 4.1. Regression of program length, enrollment, and program on the yearly cost of selected vocational programs in Iowa area schools

Source		$\hat{\beta}_i$	t-value
Program length (months)		5.52	.1630
Mechanical drafting	[3][a]	-172.80	-.3216
Mechanical technology	[7]	491.07	1.4104
Refrigeration, etc.	[4]	-372.77	-.8122
Welding	[10]	73.47	.1460
Enrollment		-36.17	-3.3711**
Intercept ($\hat{\beta}_o$)	[10]	2581.65	3.4740**

[a]Numbers in [ ]'s indicate the number of schools having that type program. The number on the intercept represents the number of schools offering an electronics technology program.

**Significant at .99 level.

Table 4.2. ANOV: Program length, enrollment, and program on vocational training costs

Source	D.F.	Sum of squares	Mean square	F-ratio	R^2
Regression	6	9341219.61	1556869.94		
Residual	27	12496663.4	462839.38	3.3637*	.428
Total	33	21837883.0			

*Significant at .95 level.

The low significance level applied to the $\hat{\beta}$-coefficients of the program variables likely reflect the lack of sufficient observations of the programs. This is particularly understandable when considerable variance is introduced by differences between area schools. Eliminating this source of variation would cost 17 degrees of freedom in the regression analysis, leaving only 10 degrees of freedom for the residual. For this reason and because we are interested in estimating the expected cost of particular types of vocational programs across the existing quality range of schools, dummy variables for schools were not introduced in the multiple regression analysis. The use of multiple regression for estimation is superior to the use of simple averages of cost per unit of time for each of the program types, because of the small number of observations on which some averages would be based. Multiple regression estimation also accounts for the very significant effect of enrollment, which might be lost in the use of simple averages.

The $\hat{\beta}$'s are the least square estimators of the β's. This is unchanged by high variability of the independent variables used in estimation. Realizing that the coefficients estimated may have a fairly large error, they were still used as the best available estimators of vocational training costs.

Any vocational training program which could not be closely identified with one of the five programs from the Cage study was assigned the average cost over all five programs. This cost was $1902.97 per year, or $158.58 per month.

Costs of the five programs from the Cage study were calculated from the multiple regression analysis, under the assumption that, for each program, the average length of program[1] and the average enrollment for that program were the actual values. Table 4.3 presents the average length, average enrollment, and the calculated cost of the programs per year and per month. The social costs of vocational education were projected to increase at six percent per year.

Table 4.3. Social costs of vocational education programs

Program	Av. length in months	Av. enrollment	Cost Per year	Cost Per month
Electronics technology	19.8	32.4	$1519.04	$126.59
Mechanical drafting	11.0	25.7	1540.00	128.33
Mechanical technology	19.3	23.6	2325.64	193.80
Refrigeration, etc.	15.0	16.3	1702.11	141.84
Welding	8.6	14.5	2178.13	181.51
Average			1902.97	158.58

[1]The length of program i, times its $\hat{\beta}_i$, indicates the effect of increased length of program on the cost of that program for a standard unit of time. In this case the unit of time used was one year. The average length of the program is used because of possible correlation with program type, and the resulting simplicity of the model application.

3. Occupation activity parameters

a. Cross-sectional wage profiles   The survey information on wages consisted of the starting and the top wages for each occupation. This information indicated the relative level of wages which might be expected in each occupation. It was not sufficient, however, to make any projection of wages over an individual's expected upward occupational movements over his lifetime. As such projections were necessary to estimate present-values of expected incomes for application in the applied model, additional sources had to be consulted.

Journal articles by Herman P. Miller (53), H. S. Houthakker (37), and W. Lee Hansen (33) dealt with expected lifetime income by level of general education. The most recent of these studies used 1958 data. All three studies are based on census data of average income, divided into six to twelve age groups and six to nine general education groups. Since these articles were published more recent census data have become available.

A Department of Commerce publication on the expected value of estimated lifetime earnings presents the average income for 1959 by broad occupational groupings as well as bi-yearly age categories and three general education categories (86). This study indicated that, at early ages, workers in the craftsmen, foremen, and kindred workers category tended to have slightly higher earnings than did all workers, but they had lower earnings at the older ages. This held true in all education groups, except eighth grade, where craftsmen, foremen, and kindred workers tended to have somewhat higher earnings at all age levels. The advantages of breakdowns by occupation category are diminished by the realization that workers starting in a given occupation category often expect to eventually move to other occupational categories before retirement.

Another Department of Commerce publication presented annual mean income by education and age for selected years, through 1966 (84). Those data were used to estimate expected levels of income, within the structure of the model. This choice was made because of the current nature of the data. This data on 1966 mean income were presented for yearly age categories from age 18, to age 64. All figures were adjusted by mortality rates to reflect the expected income of a person currently 18, at each year in the future. For use in the educational investment model these figures were readjusted by mortality rates so they reflected the expected income of a person at each age, given he lived to the completion of the year. This adjustment was necessary because the model treated individuals with any entry age.

Regression analysis was used to fit these adjusted values for education categories corresponding to those of the model. These education categories were: elementary school, eight years; high school, one to three years; high school, four years: and college, one to three years. It was found that, in all education categories, the income profile was fit well by a parabolic (or quadratic) function of the type, $y = ax^2 + bx + c$, where y represents age and x represents average income.[1]

[1]The parabola fit by this equation is of the form: $y = (\frac{1}{4p})\, x^2 + (-\alpha/2p)\, x + (\alpha^2 + 4p\delta)/4p$. The focus is $(\alpha, p + \delta)$ and the directrix has the equation $y = \delta - p$.

The equation was used to estimate an x-value for a given y. There may be two real values of x corresponding to a given y in which case the larger x is used for the projection of wages. Using only the largest x values eliminates the bottom half of the parabola, which would have shown decreasing income over time.

Table 4.4 presents the results of the discussed regressions. The R^2 values indicate that the parabolic function gave a very good fit in all education categories, except the college category where the fit was still deemed adequate.

Table 4.4. Estimated parameters for parabolic representation of cross-sectional income, by education categories

Education	Intercept	$\hat{\beta}_1$[a] Value	$\hat{\beta}_1$[a] t-value	$\hat{\beta}_2$[a] Value	$\hat{\beta}_2$[a] t-value	R^2
8th grade	25.622	-.01466	-8.8673**	$.2358 \times 10^{-5}$	14.3307**	.9747
1-3 years H.S.	10.460	-.006709	-8.1668**	$.1203 \times 10^{-5}$	15.4242**	.9683
H.S. graduation	13.269	-.006246	-10.8460**	$.8919 \times 10^{-6}$	20.6801**	.9864
1-3 years college	5.682	-.002390	-2.1548**	$.4305 \times 10^{-6}$	5.5068**	.8547

[a]$\hat{\beta}_1$ is the coefficient for x and $\hat{\beta}_2$ is the coefficient for x^2.

Having 1) the cross-sectional wage estimates, by education category, and 2) the starting and top wages by occupation, within each education group, these two items had to be brought together to form a single measure of expected payoffs. The objective of this merger was the projection of income, by years since entry and by occupation.

Observation of the starting and top wages from the survey information suggested that the entry wage might have been lowered in some cases by the inclusion of individuals who were actually still in training (at least part time) for the occupation. To help raise such low figures and to give a better overall index of wages in a particular occupation, a new wage figure was calculated for each occupation. This new value was a weighted average of the starting and top wages, with the beginning wage weighted two-thirds and the top wage weighted one-third.

The weighted wage for an occupation was compared to the beginning wage of the cross-sectional wage schedule for that education category. If they were the same the cross-sectional wage schedule was used, unchanged for the wage schedule of the occupation. If the weighted wage was different from the beginning cross-sectional wage the entire schedule of wages was shifted and this shifted wage schedule was then used for the occupation.

When the weighted wage was above the beginning cross-sectional wage (the most prevalent occurrence) the schedule of wages was shifted both upward and to the left. The schedule was first shifted upward by one-third of the difference. This adjustment presumes that one-third of the difference in the two wages is permanent and will be reflected in that same absolute difference of the expected wages, at all time periods. The remaining two-thirds of the difference in the weighted and starting cross-sectional wages was compensated for by shifting the newly raised schedule of wages to the left, until the initial value of the wage schedule is the same as the weighted wage. The programming model uses annual wage estimates rather than a continuous wage function. Thus, the wage schedule was shifted to the left until the minimum difference between the weighted wage and the cross-sectional wage value was reached. The result may have left a small difference in the weighted wage and the initial wage actually used.

If the weighted wage was greater than the beginning cross-sectional wage, the entire cross-sectional schedule was shifted downward by two-thirds of the difference in the wages. It was not possible to use the same procedure as was used when the weighted wage was smaller, because of the manner in which wages were estimated. The wage schedule could not be shifted to the right because the parabolic estimation procedure would then give imaginary income values in the earlier periods.

The same values and projection methods were used for social values as were used for private values. It was assumed that the market value of an occupational service was the best measure of that service's contribution to total output for the economy. This meant that marketable output of the economy was used as the single component of social output.

b. Projection of the general wage level Estimates of wages, as determined by the length of time in an occupation, were based on cross-sectional data. These figures had to be adjusted over a time dimension so they would apply to expected wages over a lifetime. To make such an adjustment past wage trends were projected to the future. Time-series wage data were found in breakdowns by 1) Standard Industrial Classifications (SIC's), for Iowa (90), 2) job classification within specific firms (86), and 3) education level for the entire U.S. (84).

It was decided that the SIC data could not be correlated accurately with occupational categories. Also, only small differences between the classifications were reflected in the wage projections. Data specific to a certain firm raised the doubt that such figures might not be representative of all firms. There also appeared to be no accurate method to correlate the occupational classifications of the firms to those of the model.

In addition to the process of elimination two other good reasons can be given for using breakdowns by education. Differential projections by educational level can be accurately applied to components of the model, as it is similarly divided. It was also found that large differentials, both in wages and in the projections of these wages, existed between the education categories.

Average wage figures were used for the education categories: eighth grade, 1-3 years of high school, high school diploma, and 1-3 years of college. The time period covered was 1956 through 1966, with data existing only for the years 1956, 1958, 1961, 1963, 1964, and 1966. A simple linear regression analysis was used to fit the wage, as the dependent variable, with the coded year as the independent variable. Regressions were run with wages in both current dollars and with wages corrected to 1966 prices. Regression coefficients significant at the .99 level, were obtained in all regressions and there were good fits with the lowest R^2 being 0.7670. It was found that in every education category better fits were obtained using current prices. Using current prices the lowest R^2 was 0.9553. Thus, the wage projection in current prices was chosen for use in the model. Since these projections were in money wages no additional adjustment for price level changes was necessary.

The results of the regression analysis in current prices are shown in Table 4.5. Model adjustments were made by multiplying the number of years distant from the initial period by the $\hat{\beta}_1$-coefficient and adding this product to the cross-sectional wage projection.

Table 4.5. Linear regression results of years on average yearly wage in current dollars, by education category, for the years 1956-66

Education	$\hat{\beta}_0$ Intercept	$\hat{\beta}_1$ Slope	D.F.	t-value	R^2
8th grade	3406.65	127.93	4	12.4313**	.9747
1-3 yrs. H.S.	4013.11	189.38	4	9.2494**	.9553
H.S. diploma	4711.33	234.40	4	9.8958**	.9605
1-3 yrs. college	5596.09	272.72	4	12.9477**	.9765
Total	4026.24	242.92	4	15.7957**	.9840

4. Non-activity parameters

In addition to the activity parameters just covered some additional parameters must be specified for the model.

Built into the model is the probability of not being in the labor force at a particular time to realize returns which is the most easily quantified element of risk involved in the activity returns. This possibility can be separated into its components of death, disability, and unemployment.

a. Unemployment and disability The probability of unemployment would be expected to be widely variable between occupations. The importance of unemployment lies, of course, in its expected length as well as in its probability of occurrence. No information could be found on the probability of unemployment identified by categories such as those of the model. Since the occupations represented in the model are those which the survey indicated now had vacancies, and which were difficult to fill, it was decided to attempt no adjustments for unemployment.

Data from the Bureau of Labor Statistics on job injury rates indicated that expected loss of working time from injuries was fairly small (91). The average number of working days lost from job injury were calculated for the industry groups: SIC 33, SIC 34, and SIC 35. These were those industries sampled in the survey. Estimates were calculated for the years 1963, 1964, and 1965 as these were the most current years for which data was available. It was estimated that the proportions of working time lost from injury were: 1963 - .00528; 1964 - .00588; and 1965 - .00652.

The injury factor is important to individual decisions in the model only as it is reflected in an effect upon expected income. It was not known what percentage of the injuries resulted in the total loss of income. For the remaining injuries the loss of wage income was replaced by other compensation. It might be expected that the largest percentage of injuries are so compensated. The effect of injuries on the number of days worked is probably a little over one-half of one percent and the loss of income caused by injury, considerably less than this. The loss of days worked would represent a decline in society's return and the smaller, loss of income, a decline in individual returns. However, both were so small that the effect of injury on returns was neglected as a possible adjustment in the valuation of activity returns.

b. Mortality Mortality rates were used to approximate the probability of not receiving income in a particular period. The mortality rates were adjusted to reflect the probability of a person presently at a given age being alive in each of the future years. As an example, a white male, presently age 59 has a probability of .9278 of living to realize income during age 64. Thus, the present-value of income expected at age 64, before mortality adjustments, was multiplied by .9278 to give what might more accurately be called the present-expected-value of income received at age 64.

The mortality data used originated from the Division of Vital Statistics, National Center for Health Statistics (52). These figures related the number of deaths per one-thousand white males, for each age group. The deaths per thousand were divided by one-thousand to give a probability, having reached a certain age, of dying during that age. This figure will be called the mortality rate.

The probability of surviving a particular year is one minus the mortality rate for that particular age, multiplied by the probability of ever reaching that age. The probability of reaching a particular age is the survival rate of the previous period. The survival probability profiles, for each current age, were calculated by the following formula.

$$S_{\alpha i} = S_{\alpha i-1}(1 - r_{\alpha+i-1}) \quad i = 1,2,\ldots,65 - \alpha + 1, \text{where} \qquad (4.3)$$

$S_{\alpha i}$ = the probability of surviving to realize income, i years in the future, for a person currently α years old

r_j = the probability of the average person dying when j years old (i.e. the mortality rate)

Mortality adjustments were applied equally to private and social returns.

c. Other parameters Other parameters of the model are individual characteristics and the discount rate, both private and social. In applying the model, these parameters were changed to show their impact on the values of different activity paths.

The current location of the individual could be at any event point or in any activity within the activity network. If currently in an education activity the individual's length of time in that activity was specified to allow adjustment of the time and the cost to complete the activity. If presently in an occupation activity the current wage was specified so that the present-value of staying in the occupation could be properly adjusted for experience gained in that employment. This adjustment was made by moving the schedule of wages upward by one-third of the difference between the weighted and cross-sectional wage, as done for other occupations. The schedule was then moved to the left until the starting cross-sectional wage was the same as the current wage the person was receiving.

The current age of the person, in years and months, was specified. This, in turn, specified the length of all activity paths, which lasted until retirement at age 65. The age also specified the set of mortality adjustments to use.

The discount rate was also specified for both private and social value calculations. A number of different rates were used to present different possible situations. More will be said about discount rate in the next chapter.

V. RESULTS

A. Method of Application

As shown previously the application of this model to Iowa metal-trades yields results limited in their applicability to the universe sampled. This limitation is to be noted because the choice of an occupation for a person is realistically made from the entire universe of existing occupations while the occupations of significance to the applied model are only a small part of this total. However, it should be expected that the influence of education on earnings is still reflected in such a sampled subsection of total occupations because such occupations are in competition for employees with all other occupations in the economy.

The model, designed to handle numerous parametric changes and a very large number of combinations of these parameters, will be used here to present the effects of selected sets of these parameters on: (1) the present-value of different occupations, (2) the ranking of the occupations by present-values, and (3) the desirability of increased education measured through the rank of occupations by educational prerequisites category.

All runs of the model were made with both private and social values and discount rates. The specification of these private and social values was explained in the previous chapter.

All runs were also made on several personal discount rates and several social discount rates. The personal discount rates used were 5 percent, 8 percent, and 15 percent. These rates were chosen to approximate three financial conditions which an individual might face. The 5 percent approximates the rate of return which can be expected on savings in commercial banks and savings and loan institutions, or government savings bonds. The 8 percent rate approximates the lowest interest rate which might be expected on a secured loan, such as a mortgage. The 15 percent rate approximates the lowest expected rate on a nonsecured loan. These discount rates are used to represent individuals in different financial positions. The 5 percent rate is used for individuals in a very secure financial position and the 15 percent rate for the very poor or those in financial difficulties. In fact, it could be argued that the very poor may face a discount rate considerably greater than the 15 percent figure.

The social discount rates used are 3 percent, 5 percent, and 7 percent. These rates were not chosen only to represent different situations, as were the different personal rates but were chosen to present a range used in this area where there appears to be no general agreement on what the social discount rate should be. These three rates are used allowing the reader to select that rate which he most prefers. The use of three rates also points out the effect of the social discount rate on the social present-value of education. While these rates cover the range of more often used social discount rates an even higher discount rate, based on the opportunity cost of public funds, has been advocated (7).[1]

The model was run for individuals of two quite different ages to show the effect of age on payoffs from education. The first age used was 18 years to indicate the situation for a youngster who is a new, or quite recent, entrant to the labor force. The other age was 55 years which indicated the situation faced by an individual who has ten years remaining until retirement.

At both ages under each of the discount rates and both private and social values, individuals were treated who presently had an eighth grade education, two years of high school, and a high school diploma.

B. Findings

Each run of the model gave the following items: (1) a listing of all 89 occupations identified for Iowa metal-trades, ranked from largest to smallest by the present-value of their total activity path; including the cost of educational prerequisites and returns from the occupation; and (2) the difference in the present-value for each activity from that of the top ranked activity. Summary tables of these applications are presented to show more clearly, in a condensed form, the results of these model applications.

Table 5.1 indicates the importance of acquiring more education

[1]As will be shown in the following results, under the costs and returns data of this model, the principal difference in social and private present-values, arises from the discount rate used, particularly over longer periods. Thus, a rough idea of the results of a higher social discount rate can be gained by looking at the effects of the .08 and .15 personal discount rates on personal returns.

Table 5.1. Highest rank of an occupation requiring each level of general education by age, present education level, social or private values, and various discount rates

Present level of education	Type value: Soc.	Type value: Priv.	Discount rate	Rank of highest ranked occ. requiring: 8th or less	Some H.S.	H.S. dip.	Some col.
Age = 55							
8th or less		x	.15	1	25	38	84
		x	.08	1	21	38	86
		x	.05	1	15	37	84
	x		.07	1	20	38	84
	x		.05	1	20	37	84
	x		.03	1	15	37	83
Some H.S.		x	.15	2	1	35	82
		x	.08	2	1	21	83
		x	.05	2	1	11	76
	x		.07	2	1	17	77
	x		.05	2	1	14	76
	x		.03	2	1	11	71
H.S. diploma		x	.15	16	35	1	67
		x	.08	36	38	1	44
		x	.05	30	8	1	31
	x		.07	27	8	1	42
	x		.05	29	8	1	31
	x		.03	33	9	1	27
Age = 18							
8th or less		x	.15	1	13	33	70
		x	.08	2	1	5	6
		x	.05	41	9	3	1
	x		.07	4	1	3	2
	x		.05	36	8	3	1
	x		.03	61	24	3	1
Some H.S.		x	.15	2	1	10	65
		x	.08	42	1	3	2
		x	.05	65	9	3	1
	x		.07	53	1	4	2
	x		.05	65	8	3	1
	x		.03	66	26	3	1
H.S. diploma		x	.15	41	9	1	28
		x	.08	60	31	3	1
		x	.05	65	43	3	1
	x		.07	60	35	3	1
	x		.05	65	42	3	1
	x		.03	66	52	3	1

under each of the parameter combinations. Shown is the rank of the highest ranked occupation with each of the indicated general education prerequisites.

For a person currently of age 55 it is shown that for each present level of education the top rated occupation is one requiring that same level of education for entry, for both private and social returns and under all of the discount rates used. This shows that even when using the social returns and a 3 percent social discount rate, additional general education can not be justified for a person of 55 who presently has one of the indicated levels of general education. The nearest that additional education comes to being optimal is for the social values, discounted at 3 percent for a person now having two years of high school, where completion of high school could qualify him for the eleventh ranked occupation. However, this means that there are ten higher valued occupations which require no additional education.

For a person of age 18 the use of social or private values, the discount rate, and the present level of education, become quite important in determining the desirability of investing in education. The general trend observed is that additional educational investments become less desirable as the discount rate becomes higher. This result is expected since educational investments defer income; meaning that the present-value of such income becomes lower as the discount rate rises. While this general trend can be observed in the relative rankings at age 55 it is much more pronounced at age 18 where the optimal level of education is sensitive to the discount rate used.

For a person with discount rate 15 percent and an eighth grade education, the twelve highest ranked occupations require only an eighth grade education or less, and there is no indicated financial incentive to continue in the general education process. The highest rank of an occupation requiring high school graduation is 33 and the highest rank of an occupation requiring some college is 70. Under an 8 percent discount rate a major change is realized. While the four highest ranked occupations do not require high school graduation the occupation of rank five does have such a requirement. This movement has been from rank 33 under the 15 percent discount rate to rank five under the 8 percent rate. With a 5 percent discount rate, for a person currently having an eighth grade education, the highest ranked occupation required some college and the top eight occupations require at least high school graduation.

Under a 7 percent social discount rate a situation approaching indifference to the desired amount of general education exists; as the top ranked occupation requires some high school, some college has rank two, high school diploma has rank three, and no additional education has rank four. Under a 5 percent social discount rate the seven top rated occupations require at least high school graduation and the top 35 occupations require at least some additional general education. With a 3 percent social discount rate the 23 top ranked occupations require high school graduation and the top 60 require at least some additional general education.

A person of 18, who has completed two years of high school has more incentive to continue in the general education process than he does when presently having completed only the eighth grade. For personal returns, under a discount rate of 15 percent, the highest rank of an occupation requiring high school graduation has moved from 33 to 10. Under an 8 percent discount rate the highest rank of an occupation requiring high school graduation is three rather than five, and the highest rank of an occupation requiring some college is two rather than six. The ranking of occupations by social returns is virtually unchanged from a person having an eighth grade education to one having completed two years of high school.

For a person having completed high school only the case for individual returns discounted at 15 percent does not show the optimality of continuing education through some college. In this situation the 27 highest ranked occupations require no additional general education. In all cases, except private returns at a 15 percent discount rate, the occupation of rank three requires no additional general education. This is partially a result of having only four occupations in the total of 89 which require some college for entry. A more complete view of the occupational rankings can be gained by studying Tables 5.2 through 5.7.

Tables 5.2 through 5.7 present much more complete information about the results of model application than did Table 5.1. These tables deal with a person of age 18, leaving out the case of a person of age 55, where the effects of parameter changes are much less pronounced. In fact, for age 55 in several instances the rankings of occupations would have been identical for all levels of a variable (such as the discount rate) while the level of all other factors was fixed. Each table represents one of the six possible combinations of (1) three education levels at entry (eighth grade, some high school, or high school graduation) and (2) either private or social values. For each of the six tables the three discount rates, whether private or social, are presented as separate sections with the twelve occupations having the largest present-value listed in order of present-value. Each occupation is completely identified by its job number and the level of education needed for entry. The present-values apply to the entire activity path ending in the indicated occupation. Each occupation is then identified by the rank it holds for social and private returns and for each discount rate. Jobs identified by "b" require two months or more of vocational education for entry.

In very general terms the tables indicate that the private desirability of vocational education is affected by the discount rate and the level of general education presently attained. Investments in vocational education appear to become more desirable as interest rates lower and the level of general education completed increases. Tables 5.2 through 5.4, present private returns for each of the three personal discount rates. The quantities of occupations which required vocational education are: six,for eighth grade or less; ten, for two years of high school; and thirteen, for high school graduation. The numbers of occupations requiring vocational education summed, over the education categories

Table 5.2. The twelve most privately optimal occupations at age 18; eighth grade education, or less; and various discount rates

Disc. rate	Job no.	Present-value (dollars)	Level of education needed[a]	Rank of occupation: Private rate .15	Private rate .08	Private rate .05	Social rate .07	Social rate .05	Social rate .03
.15	5041	54404	1	1	2	41	4	36	59
	6381	53843	1	2	3	42	6	40	61
	0311	52999	1	3	4	50	12	43	63
	6041	52212	1	4	8	58	13	54	66
	5181	51243	1	5	14	63	17	60	69
	5191	50330	1	6	16	65	22	64	71
	5141	48613	1	7	25	69	36	69	72
	6001	48369	1	8	30	72	40	70	73
	6091	48317	1	9	31	73	43	71	74
	8011	48274	1	10	33	74	44	74	75
	7411	47565	1	11	41	76	53	76	76
	8121	47498	1	12	42	77	54	77	77
.08	6381	108916	2	13	1	9	1	8	24
	5041	107914	1	1	2	9	1	8	24
	6381	106971	1	2	3	42	6	40	61
	0311	105522	1	3	4	50	12	43	63
	0311	104994	3	30	5	3	3	3	3
	0701[b]	104701	4	84	6	2	5	1	1
	0121[b]	104555	4	70	7	1	2	2	2
	6041	104183	1	4	8	58	13	54	66
	6002[b]	103772	2	31	9	26	18	23	41
	0741	102914	3	33	10	4	7	4	5
	6371	102891	3	34	11	5	8	5	6
	0121	102809	3	41	12	6	11	6	4
.05	0121[b]	194570	4	70	7	1	2	2	2
	0701[b]	194450	4	84	6	2	5	1	1
	0311	185395	3	30	5	3	3	3	3
	0741	182174	3	33	10	4	7	4	5
	6371	182137	3	34	11	5	8	5	6
	0121	182015	3	41	12	6	11	6	4
	6011	181763	3	37	13	7	9	7	7
	8121	181040	3	38	15	8	10	9	10
	6381	180484	2	13	1	9	1	8	24
	6201[b]	178252	3	47	17	10	16	10	11
	7031	177968	3	42	18	11	14	11	14
	8011	177457	3	43	20	12	15	12	17

[a]General education requirements for entry: 1=eighth grade; 2=some high school; 3=high school diploma; 4=some college, here and throughout.

[b]Occupations which require an average of at least two months vocational education for entry, here and throughout.

Table 5.3. The twelve most privately optimal occupations at age 18; two years of high school; and various discount rates

Disc. rate	Job no.	Present-value (dollars)	Level of education needed[a]	Rank of occupation: Private rate .15	Private rate .08	Private rate .05	Social rate .07	Social rate .05	Social rate .03
.15	6381	61083	2	1	1	9	1	8	26
	5041	54413	1	2	42	65	53	65	66
	6381	53852	1	3	48	67	60	67	67
	6001	53388	2	4	25	53	26	48	55
	6061	53281	2	5	26	54	27	50	56
	0311	53007	1	6	54	68	62	68	68
	6041	52220	1	7	64	69	68	69	69
	7411	51857	2	8	35	58	42	57	58
	6002	51844	2	9	5	28	14	25	42
	0311	51625	3	10	3	3	4	3	3
	8101	51456	2	11	40	59	43	59	59
	5181	51252	1	12	69	70	70	70	70
.08	6381	125007	2	1	1	9	1	8	26
	0701[b]	120838	4	84	2	1	3	1	1
	0311	120494	3	10	3	3	4	3	3
	0121[b]	120494	4	65	4	2	2	2	2
	6002[b]	119241	2	9	5	28	14	25	42
	0121	118657	3	21	6	4	7	4	4
	0741	118032	3	14	7	5	5	5	7
	6371	118006	3	16	8	6	6	6	8
	6011	117731	3	17	9	7	8	7	9
	8121	117201	3	20	10	8	9	9	10
	6201[b]	116047	3	32	11	10	10	10	11
	6012[b]	115134	3	58	12	13	17	14	13
.05	0701[b]	216564	4	84	2	1	3	1	1
	0121[b]	215957	4	65	4	2	2	2	2
	0311	204833	3	10	3	3	4	3	3
	0121	201888	3	21	6	4	7	4	4
	0741	201213	3	14	7	5	5	5	7
	6371	201171	3	16	8	6	6	6	8
	6011	200749	3	17	9	7	8	7	9
	8121	199932	3	20	10	8	9	9	10
	6381	199197	2	1	1	9	1	8	26
	6201[b]	197955	3	32	11	10	10	10	11
	7031	196483	3	22	14	11	11	11	16
	7412[b]	196371	3	36	13	12	14	25	42

Table 5.4. The twelve most privately optimal occupations at age 18; a high school diploma; and various discount rates

Disc. rate	Job no.	Present-value (dollars)	Level of education needed[a]	Rank of occupation: Private rate .15	.08	.05	Social rate .07	.05	.03
.15	0311	66162	3	1	3	3	3	3	3
	0741	64424	3	2	5	5	5	5	7
	6371	64407	3	3	6	6	6	6	8
	6011	64227	3	4	7	7	7	7	9
	8121	63878	3	5	8	8	8	8	10
	0121	63161	3	6	4	4	4	4	6
	7031	62188	3	7	13	12	10	10	8
	8011	61941	3	8	15	14	11	14	19
	6381	61083	2	9	31	43	35	42	52
	6201[b]	60944	3	10	9	9	9	9	12
	6261	60530	3	11	20	13	18	13	11
	7412[b]	60294	3	12	12	11	12	11	15
.08	0701[b]	140479	4	53	1	1	2	1	1
	0121[b]	139479	4	28	2	2	1	2	2
	0311	138325	3	1	3	3	3	3	3
	0121	136275	3	6	4	4	4	4	6
	0741	135417	3	2	5	5	5	5	7
	6371	135385	3	3	6	6	6	6	8
	6011	135060	3	4	7	7	7	7	9
	8121	134433	3	5	8	8	8	8	10
	6201[b]	133221	3	10	9	9	9	9	12
	6012[b]	132404	3	27	10	10	13	12	13
	0321	132088	3	42	11	13	18	13	11
	7412[b]	132018	3	12	12	11	12	11	15
.05	0701[b]	238596	4	53	1	1	2	1	1
	0121[b]	237148	4	28	2	2	1	2	2
	0311	223103	3	1	3	3	3	3	3
	0121	220034	3	6	4	4	4	4	6
	0741	219052	3	2	5	5	5	5	7
	6371	219006	3	3	6	6	6	6	8
	6011	218531	3	4	7	7	7	7	9
	8121	217616	3	5	8	8	8	8	10
	8121	217616	3	5	8	8	8	8	10
	6201[b]	215690	3	10	9	9	9	9	12
	6012[b]	214074	3	27	10	10	13	12	13
	7412[b]	213912	3	12	12	11	12	11	15
	7031[b]	213758	3	7	13	12	10	10	16

Table 5.5. The twelve most socially optimal occupations at age 18; an eighth grade education; or less, and various discount rates

Disc. rate	Job no.	Present-value (dollars)	Level of education needed[a]	Rank of occupation: Private rate .15	Private rate .08	Private rate .05	Social rate .07	Social rate .05	Social rate .03
.07	6381	126311	2	13	1	9	1	8	24
	0121[b]	125018	4	70	7	1	2	2	2
	0311	124274	3	30	5	3	3	3	3
	5041	123521	1	1	2	41	4	36	59
	0701[b]	123374	4	84	6	2	5	1	1
	6381	122479	1	2	3	42	6	40	61
	0741	121889	3	33	10	4	7	4	5
	6371	121863	3	34	11	5	8	5	6
	6011	121594	3	37	13	7	9	7	7
	8121	121074	3	38	15	8	10	9	10
	0121	120993	3	41	12	6	11	6	4
	0311	120872	1	3	4	50	12	43	63
.05	0701[b]	192400	4	84	6	2	5	1	1
	0121[b]	192316	4	34	11	5	2	2	2
	0311	183622	3	30	5	3	3	3	3
	0741	180401	3	33	10	4	7	4	5
	6371	180364	3	34	11	5	8	5	6
	0121	180115	3	41	12	6	11	6	4
	6011	179991	3	37	13	7	9	7	7
	6381	179782	2	13	1	9	1	8	24
	8121	179267	3	38	15	8	10	9	10
	6201	176320	3	47	17	10	16	10	9
	7031	176196	3	42	18	11	14	11	14
	8011	175684	3	81	22	17	30	12	17
.03	0701[b]	313657	4	84	6	2	5	1	1
	0121[b]	310074	4	70	7	1	2	2	2
	0311	285731	3	30	5	3	3	3	3
	0121	282255	3	41	12	6	11	6	4
	0741	281190	3	33	10	4	7	4	5
	6371	281136	3	34	11	5	8	5	6
	6011	280590	3	37	13	7	9	7	7
	0742[b]	279974	4	89	83	29	73	29	8
	0741[b]	279950	4	88	71	21	60	22	9
	8121	279536	3	38	15	8	10	9	10
	6201[b]	277287	3	47	17	10	16	10	11
	0321	276400	3	81	22	17	30	17	12

Table 5.6. The twelve most socially optimal occupations at age 18; two years of high school; and various discount rates

Disc. rate	Job no.	Present-value (dollars)	Level of education needed[a]	Rank of occupation: Private rate .15	.08	.05	Social rate .07	.05	.03
.07	6381	144031	2	1	1	9	1	8	26
	0121[b]	143214	4	65	4	2	2	2	2
	0701[b]	141894	4	84	2	1	3	1	1
	0311	141786	3	10	3	3	4	3	3
	0741	139013	3	14	7	5	5	5	7
	6371	138983	3	16	8	6	6	6	8
	0121	138847	3	21	6	4	7	4	4
	6011	138670	3	17	9	7	8	7	9
	8121	138064	3	20	10	8	9	9	10
	6201[b]	135682	3	32	11	10	10	10	11
	7031	135407	3	22	14	11	11	11	16
	8011	134979	3	26	16	14	12	13	17
.05	0701[b]	215192	4	84	2	1	3	1	1
	0121[b]	214377	4	65	4	2	2	2	2
	0311	203736	3	10	3	3	4	3	3
	0121	200660	3	21	6	4	7	4	4
	0741	200116	3	14	7	5	5	5	7
	6371	200074	3	16	8	6	6	6	8
	6011	199652	3	17	9	7	8	7	9
	6381	199197	2	1	1	9	1	8	26
	8121	198835	3	20	10	8	9	9	10
	6201[b]	196694	3	32	11	10	10	10	11
	7031	195386	3	22	14	11	11	11	16
	7412	195111	3	36	13	12	13	12	15
.03	0701[b]	343408	4	84	2	1	3	1	1
	0121[b]	338568	4	65	4	2	2	2	2
	0311	310376	3	10	3	3	4	3	3
	0121	307150	3	21	6	4	7	4	4
	0742[b]	306364	4	88	53	22	45	22	6
	0741	305421	3	14	7	5	5	5	7
	6371	305363	3	16	8	6	6	6	8
	6011	304764	3	17	9	7	8	7	9
	8121	303605	3	20	10	8	9	9	10
	6201[b]	301945	3	32	11	10	10	10	11
	0321[b]	301853	3	78	15	15	20	15	12

Table 5.7. The twelve most socially optimal occupations at age 18; a high school diploma, and various discount rates

Disc. rate	Job no.	Present-value (dollars)	Level of education needed[a]	Rank of occupation: Private rate .15	Private rate .08	Private rate .05	Social rate .07	Social rate .05	Social rate .03
.07	0121[b]	163175	4	28	2	2	1	2	2
	0701[b]	162331	4	53	1	1	2	1	1
	0311	159996	3	1	3	3	3	3	3
	0121	156812	3	6	4	4	4	4	6
	0741	156781	3	2	5	5	5	5	7
	6371	156745	3	3	6	6	6	6	8
	6011	156381	3	4	7	7	7	7	9
	8121	155677	3	5	8	8	8	8	10
	6201[b]	153197	3	10	9	9	9	9	12
	7031	152598	3	7	13	12	10	10	16
	8011	152100	3	8	15	14	11	14	19
	7412[b]	151841	3	12	12	11	12	11	15
.05	0701[b]	238323	4	53	1	1	2	1	1
	0121[b]	236662	4	28	2	2	1	2	2
	0311	223103	3	1	3	3	3	3	3
	0121	219900	3	6	4	4	4	4	6
	0741	219052	3	2	5	5	5	5	7
	6371	219006	3	3	6	6	6	6	8
	6011	218532	3	4	7	7	7	7	9
	8121	217616	3	5	8	8	8	8	10
	6201[b]	215522	3	10	9	9	9	9	12
	7031	213758	3	7	13	12	10	10	16
	7412[b]	213745	3	12	12	11	12	11	15
	6012[b]	213607	3	27	10	10	13	12	13
.03	0701[b]	369586	4	53	1	1	2	1	1
	0121[b]	363617	4	28	2	2	1	2	2
	0311	331376	3	1	3	3	3	3	3
	0742[b]	330594	4	86	41	19	40	19	4
	0741[b]	328452	4	83	43	21	39	22	5
	0121	328146	3	6	4	4	4	4	6
	0741	326012	3	2	5	5	5	5	7
	6371	325948	3	3	6	6	6	6	8
	6011	325296	3	4	7	7	7	7	9
	8121	324036	3	5	8	8	8	8	10
	0321[b]	323410	3	42	11	13	18	13	11
	6201[b]	322576	3	10	9	9	9	9	12

within each discount rate are: three, for discount rate 15 percent; 13, for discount rate 8 percent; and 13 for discount rate 5 percent. These rankings indicate the increasing desirability of vocational education with increasing levels of general education. The effect of the discount rate on desirability of vocational education appears to be significant when going from 15 percent to 8 percent, or from 15 percent to 5 percent, but there is no obvious difference when going from 8 percent to 5 percent.

Each time an occupation is listed in Tables 5.2 through 5.7 its rank within each of the six discount rate and type of value categories is specified. While the tables contain too much information to enumerate fully in this text a few general observations and illustrative cases are presented.

The conclusion which could be reached from Table 5.1, that individuals with higher discount rates are induced to consume less general education, is supported by Tables 5.2 through 5.7. One can observe that the education requirements for the highest ranked occupations within each category increase as the discount rate declines.

Some occupations have much wider ranges of ranks than do others, under both private and social values and changing discount rates. In Table 5.2 occupation 6381 has a range of ranks from one to 24. Occupation 0701 has a range of ranks from one to 84.

While not necessarily true, one of the extremes in rank often occurs at the 15 percent private discount rate. (All future references to social discount rate or private discount rate will mean the indicated discount rate as applied to social or private values respectively.) Not only do extremes in rank tend to occur at the 15 percent discount rate but such extremes are frequently quite different from the other ranks. These extremes suggest that it might be a common experience to find an occupation which is optimal or near optimal under a private discount rate of 15 percent but far from optimal in all other situations. The reverse situation would also be suggested where occupations which are ranked quite high for all (or most) other discount rates are ranked very low under a 15 percent private discount rate. The major implication is that the choice pattern of an individual with a 15 percent private discount rate will be quite different than the choice patterns of those with 8 percent or 5 percent private discount rates and quite different than the social optimums as defined under 7 percent, 5 percent and 3 percent, social discount rates.

The relative attractiveness of occupations is assumed to be based upon their relative payoffs as reflected in present-values. (The possibility of considering, also, subjective values of the entrant is discussed in Chapter VI.) The rank of an occupation can be changed by increasing or decreasing its present-value. The effects of educational loans or grants, as discussed in Chapter II and Chapter III, is illustrated numerically in the following example. Suppose the entrant is age 18, with an eighth grade education and an 8 percent personal discount rate and that the proper social discount rate is 5 percent. The private optimum is occupation 6381, at education level 2, which has a private value of $108,916 (Table 5.2) and a social value of $179,782 (Table 5.5).

The social optimum is occupation 0701, at education level 4, with a social value of $192,400 (Table 5.5) and a private value of $104,701 (Table 5.2). To make occupation 0701 privately optimal, as well as socially optimal, and assuming no returns can be decreased, the return from 0701 must increase by some amount greater than $108,916 minus $104,701, or $4,215, in present-value.[1] A loan or grant with a personal present-value of an amount greater than $4,215 must be available to induce this individual to view occupation 0701 as optimum. He will then follow the socially optimum path, which means pursuing general education through some college rather than dropping out of high school to enter occupation 6381.

Appendix C presents a sample table of the value of educational loans in terms of their addition to present-value as formulated in Chapter III. In general, Table C.1 reflects the fact that loans add more to present-value as the interest rate decreases, the personal discount rate increases, and/or the length of payoff period increases.

Occupations identified with an initial number of five, are processing occupations. (See Appendix B for descriptions of individual occupations

---

[1]Whether such a public expenditure increases social output, where a social cost reflects on opportunity forgone, might be approximated by comparing the increase in social values, $192,400 minus $179,782, or $12,618, to the cost of the required subsidy, which is over $4,215. Only if made in a single immediate payment would the social cost and private value of a subsidy be equal. In any deferred payment procedure, with a social discount rate less than the private discount rate, the social cost would become increasingly larger than the private value as the payments became more remote. Also, no initial single payment would suffice to induce any change in private optimum without either a binding contract to complete that education, or a requirement to repay, with penalties, if the level of education for which the loan was given was not reached.

and broader occupational groups.) With one exception such processing occupations are in the top twelve occupations only for those entrants presently having less than a high school education and a personal discount rate of .15. In no case are they one of the top twelve occupations by social value.

Occupations identified with an initial number of zero, which are technical occupations, tend to be more desirable for personal discount rates of 8 percent and 5 percent than for a 15 percent personal discount rate. This is at least partially a reflection of a positive correlation of this category with higher levels of general education.

Occupations with an initial number of six, which are machine-trades occupations, appear to be equally distributed as optimal occupations, among all discount rate and present level of education combinations. These occupations are in second place, after technical occupations, for preferences in the higher level of education and lower discount rate categories.

Only five occupations identified with an initial number of eight, which are structural work occupations, appear in the top twelve occupations for any category. These occupations are 8121 and 8011, both at education levels three and one, and 8101 at education level two.

Four occupations identified with an initial number of seven, which are bench work occupations, appear in one of the top twelve categories. These occupations are 7411, at education levels one and two, and 7031 and 7412, at education level three. There is no apparent relationship between the ranking of these occupations and the discount rates or the entry levels of education.

Tables 5.1 through 5.7 contain much more information than is enumerated in the text. Such a lengthy treatment was deemed to be much more exhaustive than needed for an explanation of model results and implications. The preceding written explanations were meant to single out the more important results of application of the model. The text should be sufficient to guide the reader in further interpretation of the tables.

VI. SUGGESTED REFINEMENTS AND EXTENSIONS

A. Refinement of Procedures

The suggestions in this chapter will be separated into two sections: (1) refinements in the applied model procedure of this study, and (2) the extension of this procedure to a broader, more inclusive procedure having wider application and furnishing more generally useful results.

1. Additional considerations

a. Subjective values The expression of personal attitudes toward occupations is, of course, quite important in specifying the real worth of each occupation to a given individual. A decision model which truly reflects an individual's decision process must take consideration of such an important item.

That an attitude can be exactly quantified and combined with the present-value of an occupation is doubtful. However, an approximate measure, which is based on the methodology used to give some cardinal properties to the vonNeumann-Morgenstern utility function, is suggested here.

This method begins by first designating any one of the occupations as a base. Secondly, the relative differences between the subjective values of this occupation and those of other occupations are determined under the assumptions of instant entry and equal monetary payoffs for all occupations. The relative differences are found in the following manner: (1) for each occupation find that combination of a lump sum payment of cash and lifetime employment in an occupation which is necessary for the person to be indifferent between that occupation and the base occupation; (2) if the base occupation was formerly and initially preferred to the compared occupation, the "bribe" is attached to the base occupation; (3) when the "bribe" is added to the base occupation, this amount is added to the present-value of the other occupation so as to arrive at a present-value adjusted for occupational preferences; (4) if the "bribe" is added to the occupation being valued, this quantity is to be subtracted from the occupation's current present-value so as to adjust for preference.

While the previously presented procedure might be postulated to adjust for occupational preferences it is not apparent that preferences for education (similar to the consumption element of education) can be handled in the same manner. In fact, this researcher has no truly operational suggestions to make concerning the valuation of such psychic returns from education.

b. Risk In this study no consideration has been made of risk. While it may not hold universally, individuals are generally expected to be risk averters (particularly in cases where relatively large amounts are involved). This attitude toward risk can be expressed in several manners including: (1) a certain return of x dollars is always preferred to an uncertain return with an expected value of x dollars; or, (2) in a more general context the variance of expected returns has a negative value which changes in the same direction as the variance. Since risk has a negative value it could be expressed through a downward adjustment in the present-value of an activity path.

Risk does not affect the expected value of an activity path. Thus, adjustments of expected value for possible income loss from unemployment and the subsequent cost of movement to a new job, if still employable, are not adjustments for risk. Rather such adjustments are necessary to arrive at the true expected value of an activity path. This does not mean that the amount of risk is not affected by the amount of income lost by unemployment and relocation costs. Generally, the larger these items of risk, unemployment, and relocation costs are the higher is the variability of expected income.

The concept of risk in occupational payoffs is much more complicated than the probabilities of being employed or not employed and the effects of these on the variability of income. A major item of risk is involved in estimating what will be the rate of upward advancement and the payoff from a job at any given time. A certain risk is also incurred when undertaking an educational program where graduation is not certain.

Risk is a useful factor in explaining why general education is often preferred to vocational education and why certain vocational trades are much more zealous in trying to control job entry than are nonvocational occupations. General education is a prerequisite to many types of occupations. The more general is the education one receives, the easier it tends to be for him to find another job, thus lowering the relocation costs and risk. When such a person finds a new job, the entry level of pay will probably be near that of his former occupation. Vocational education is not readily transferable; most certainly not to the same extent as general education.[1] Thus, if a person with a large amount of vocational training finds himself out of work he may encounter considerable search costs looking for another job. If he does not find another job of the same type as his former occupation he will probably be forced to accept a job with entry wages lower than those of the job for which he is trained. This would be reflected both in risk and lower expected value.

Suppose that all adjustments are made in the expected values (expect the adjustment for risk) of an occupation requiring a large amount of vocational education for entry (occupation V) and another requiring an equivalent amount of general education (occupation G), resulting in expected values which are the same. Then, if occupation V involves more risk, occupation G will be preferred. V will be preferred only if it has an expected value exceeding the expected value of G by at least enough to compensate for the risk. Thus, an occupation requiring general education for entry may be preferred to an occupation requiring vocational education, even when the latter has a higher expected value. Thus, risk may motivate the restrictions to entry in vocational occupations, as such restrictions help to reduce the risk of such occupations, as well as their more widely recognized objective of holding wages at a level above that which would exist in an unrestricted market.

---

[1] One might view more advanced formal education, such as graduate work, in the same light as vocational education.

The risk element of a given activity path is determined, in part, by the probability of moving from that activity to each of the other activities. Once having moved from one activity to another there is a new set of probabilities of becoming unemployed in the new occupation and moving to each of the other occupations. Additional risk is added by the uncertainty attached to the expected payoffs in each activity.

It is seen that the expected present-values, as calculated in the applied model, do not reflect the probabilities of unemployment and movements to other occupations. Before such adjustments can be made, the probabilities of unemployment and of movement to other occupations would have to be quantitied. A method to arrive at accurate measures of these probabilities would have to be established. Lacking accurate measures of these probabilities the applied model took the much simpler approach of assuming equal risk and income effects of the probabilities for all activities. An identification problem also existed for the variability of activity parameters.

Risk measures might also be applied to educational activities, where such risk is determined by the probability of completing the educational program and the risk associated with the following occupations. It is also not clear how this measure of educational risk would be identified. Among other things it would be expected that the larger the number of occupations to which the education provides entry the lower is the risk. Again this gives an advantage to general education over vocational education.

c. <u>Nonquantifiable factors</u> There are characteristics of an individual, in addition to age and discount rate, which may affect his expected payoff (present-value) of occupations. Weisbrod (97) has shown that items such as marital status, race, and test scores can be important factors in explaining the level of income which an individual receives. Within the context of the model, effects on expected income might be incorporated by adjusting expected payoffs from the occupations. Within the more general framework, involving consideration of risk and probabilities of occupational movements, they may take the form of different expected payoffs and different probabilities of unemployment, or changed levels of risk.

Within the operational model a major adjustment can be made, through mortality rates, to reflect different payoffs for nonwhite and white entrants. The mortality rates for white males were used in this application of the model. At all ages the mortality rates for nonwhite males are higher than those for white males. Thus, even if living nonwhites receive the same income as whites in the same occupation and have equal opportunities for those jobs, the probability of reaching any particular age to realize that income is less. Therefore, activity paths which require more education and result in deferred income would have lower present-values and tend to be less attractive to nonwhites than to whites. By using nonwhite mortality rates in the applied model and comparing the results to those reported here, the effect of these higher mortality rates on desirability of education and ranking of occupations could be more accurately indicated.

2. Improvement of estimators

An obvious area where the accuracy of the applied model could be improved is in the data used to estimate model parameters. The availability of better data might also make feasible the consideration of more sophisticated techniques for estimation procedures.

The data on wages which were available dealt, in nearly all situations, with the average wage for a particular occupation. There is no way to use this single wage figure to indicate the expected time path of wages from that occupation. Also, an occupational grouping ignores the possible hierarchy of jobs within that occupation. To reflect accurately the payoff from a job it is necessary to know if this job is usually a terminal occupation, with little opportunity for advancement. If advancement opportunities do exist, an accurate measure of present-value should reflect the wage received from these jobs and the further advancement possibilities. The need for measures of occupational stability and the worker mobility in the occupation has already been indicated.

A study of employment projections by occupation and level of education along with the current supplies of workers with the needed skills could give some insights on employment possibilities. Such a study might also reflect on expected wage levels.

B. Extension to a Macro-Economic Model

This study has dealt with the most micro-economic level possible, the individual. It is suggested here that the individual can be aggregated to represent the labor force as being composed of groups of individuals.

When the reactions of each individual element of an aggregate can be identified, along with the interactions of these elements, then the reaction of the aggregate should also be identifiable.

The scope of the aggregation to which such a concept is applied might vary considerably from a town or city focus to a national focus. To reduce the complication of migration it may be better to consider only the larger regional or national applications of such a concept.

The formation of an operational concept is facilitated by aggregating the labor force into groups of individuals with similar characteristics. The characteristics used should be those which explain the larger portions of the quantities of labor supplied by occupational groups. Among other characteristics, the following items would likely be considered: some index of discount rate, current training, age, and perhaps the location of population by area or region. Each population group would also have to be defined by the number of individuals it included and its responsiveness to changes in those parameters which are found to be important.

The complete description of the labor force involves establishment of a set of interrelated supply functions, identifying the supply side of the labor market. Of course this is only a part of the solution with the determination of the demand functions remaining.

Perhaps an input-output projection of output by sector could be coupled with a projection of technology to determine those demands. The projection of technology would relate the demand for occupations to the level of output in each industrial sector. (The labor demands so defined are completely price inelastic.)

The objective then might be the establishment of a set of parameters affecting supply such that the expected demand is satisfied. One of these parameters, wages, would present another interaction of supply and demand since the input-output analysis assumes a particular level of consumer demand for outputs. The wages paid to workers must be sufficient to generate this amount of final consumption if the system is to reach a solution at the postulated level of consumer demand. This means that while manipulation of wages and educational costs may have the same effect on the supply of labor they will have quite different effects on labor demand since wages, but not educational costs (at least directly) affect consumer demand.

Quite obviously this presentation of a more general application is only a suggestion of an extension which may be feasible. Before undertaking such a research project, considerable work would be done on the theoretical construct and the availability of data. It may be that such an undertaking, in order to give meaningful detail, would have to be too massive for actual use.

If feasible, such an application should be able to present information on the structures of regional or national output which are consistent with the available labor force. It should also indicate expected wage levels by occupation, future composition of the labor force, and the needs for various types of educational programs.

VII. SUMMARY

A. Focus of the Study

The central focus of this study has been the development of a comprehensive model to describe the decision process of a person planning his lifetime path of educational training, leading to eventual employment. This model was developed through the application and extension of several available methods.

The model developed described the decision process of a hypothetical person who was assumed to maximize the present-value of returns. This type of model gave results applicable to general classifications of individuals.

In the applied model both social and private returns were used to show possible divergences of the two. Specific application of the model was made to metal-trades occupations in Iowa.

B. Method

1. Theoretical construct

The theoretical construct within which the model was formulated, was developed by the application of traditional capital and investment theory, as applied to the firm, to individual investments in human capital. This construct treats the individual as being a concept similar to the firm, and education as similar to physical capital. This theoretical construct is developed with the assumption of two interest rates, one a borrowing rate and the other a lending rate. The traditional capital theory was changed to incorporate the individual characteristics of being able to invest in only one type of capital at a time, and the influence of wealth holdings. The theoretical construct also dealt with the effect of educational grants and low-cost loans on the profitability of educational investments.

2. Analytical model

The analytical model was developed to formulate values, in the form of present-values, for the possible sets of educational investment and final employment available to an individual. In part, this model was a reformulation of the itinerary model, the program evaluation and review technique (PERT) and the critical path method (CPM).

This educational investment model consisted of activities, with time and value parameters; and events, which connected the activities. Three types of activities were identified. Education activities were of two types: either general education, or vocational education, with occupations being the third type of activity. The activity linkages were defined so that a continually diverging set of activity paths existed. The only event which was an end-event for more than one activity was the retirement event.

Age and personal discount rate characteristics of an individual were combined with the time and value parameters of the activities to assign present-values to each of the activities. These present-values were then summed over each of the paths to give a present-value for each combination of an occupation and its educational prerequisites. The model made certain adjustments for mortality probabilities, the existence of activities which the individual had previously fulfilled, and the current location of the individual within the network of activities.

3. Application of the model

Identification of the network of activities was the first prerequisite to application of the model. This information was available from a survey of Iowa metal-trade occupations. After identification of the network, time and value parameters had to be applied to each of the activities. General education was divided into two-year segments and its value (cost) was derived from various sources of public data. Vocational education activities were assigned time parameters as determined from the Iowa metal-trade occupations. The values (costs) of vocational education activities were also derived from several sources. Occupation activities were assigned a value through a combination of information from the survey and wage projections derived from census data. The time element of occupational activities was derived from the time required to meet educational prerequisites and the age of the entrant. Given this information the present-values of the activity paths were determined as previously indicated. Both social and private values were estimated.

C. Results and Conclusions

Application of the model was made through the use of social discount rates of 3 percent, 5 percent, and 7 percent and private discount rates of 5 percent, 8 percent, and 15 percent. Representative individuals of ages 18 and 55 were used for model application.

A number of conclusions were reached through the model application. These conclusions were:

(1) The payoff from increased education is higher for younger ages and at lower discount rates.

(2) The differences of social and private returns (as defined in the model) is largely a reflection of discount rates.

(3) More occupations requiring vocational training became optimal as the level of education presently completed increased, within the context of the sample.

(4) Educational loans, at low interest rates, are more effective in encouraging educational investments as (a) the interest rate on the loan decreases, (b) the personal discount rate increases, and/or (c) the length of payoff period increases.

(5) Processing occupations are more attractive to individuals with high discount rates.

(6) Technical occupations are more attractive to individuals with low discount rates, and generally require higher levels of general education.

(7) Machine-trades occupations appear to be attractive at all discount rates and levels of education.

(8) Structural-work and bench-work occupations appear infrequently with near optimal present-values.

VIII. BIBLIOGRAPHY

1. Altman, James W. Research on general vocational capabilities (skills and knowledges). Pittsburgh, Pennsylvania, American Institute for Research. 1966.

2. Anderson, Charles Arnold. A skeptical note on the relation of vertical mobility to education. American Journal of Sociology 66: 560-570. 1961.

3. Archibald, Russell D. and Richard L. Villoria. Network based management systems (PERT/CPM). New York, John Wiley and Sons. 1967.

4. Arizona State Employment Service, Manpower Economics Section. Arizona occupational briefs. Phoenix, Arizona, Arizona State Employment Service. 1967.

5. Arrow, Kenneth J. Social choice and individual values. New York, John Wiley and Sons. 1963.

6. Bailey, Martin J. Formal criteria for investment decisions. Journal of Political Economy 67, No. 5: 476-488. 1959.

7. Baumol, William J. On the social rate of discount. The American Economic Review 53: 788-802. 1968.

8. Becker, Gary S. Human capital: a theoretical and empirical analysis with special reference to education. New York, National Bureau of Economic Research. 1964.

9. Becker, Gary S. Investment in human capital: a theoretical analysis. The Journal of Political Economy 70, No. 5, Part 2: 9-49. 1962.

10. Becker, Gary S. and Barry R. Chiswick. The economics of education and the distribution of earnings. Annual meeting of the American Economic Association, 78th, New York, 1965. Papers and proceedings. The American Economic Review 56, No. 2: 358-369. 1966.

11. Benewitz, Maurice C. and Albert Zucker. Human capital and occupational choice - a theoretical model. The Southern Economic Journal 34, No. 2: 35-38. 1967.

12. Benson, Charles S. and Paul R. Lohnes. Public education and the development of work skills. Harvard Educational Review 29: 137-150. 1959.

13. Blaug, Martin. A selected annotated bibliography in the economics of education. London, Institute of Education, University of London. 1964.

14. Blaug, Martin. Economic theory in retrospect. Homewood, Illinois, Richard D. Irwin, Inc. 1962.

15. Bowen, William G. Economic aspects of education: three essays. Princeton, New Jersey. Industrial Relations Section, Department of Economics, Princeton University. 1964.

16. Bowen, William G. The economics of education by John Vaizey: a review. The American Economic Review 53: 235-245. 1963.

17. Bowman, Mary Jean. Social returns to education. International Social Science Journal 14, No. 4: 647-659. 1962.

18. Cage, Bobby Nyle. Cost analysis of selected educational programs in the area schools of Iowa. (Iowa State University, Ames, Iowa) Research grant VEA-1963-4(a) ancillary funds, Iowa Department of Public Instruction. 1968.

19. Cage, Bobby Nyle. Cost analysis of selected educational programs in the area schools of Iowa. Unpublished Ph.D. thesis. Ames, Iowa, Library, Iowa State University of Science and Technology. 1968.

20. Carroll, Adger B. and Loren A. Ihnen. Costs and returns for investments in technical schooling by a group of North Carolina high school graduates. Department of Economics, North Carolina State University, Raleigh, North Carolina, Economics Research Report No. 5. 1967.

21. Clark, Harold F. and Harold S. Sloan. Classrooms in the factories. Rutherford, New Jersey, Institute of Research, Fairleigh Dickinson University. 1958.

22. Corazzini, A. J. and E. Bartell. Problems of programming: an optimal choice between general and vocational education. Kyklos 18: 700-704. 1965.

23. Correa, Hector. Optimum choice between general and vocational education. Kyklos 18: 107-113. 1965.

24. Cotgrove, Steven F. Technical education and social change. London, George Allen and Unwin. 1958.

25. D'Amico, Louis A. and W. Robert Bokelman. Tuition and fee charges by public junior colleges, 1961-62. Junior College Journal 33: 36-39. 1962.

26. Denison, E. F. Measuring the contribution of education to economic growth, the residual factor and economic growth. Paris, Organization for Economic Co-operation and Development. 1964.

27. Eckaus, R. S. Economic criteria for education and training. The Review of Economics and Statistics 46, No. 2: 181-190. 1964.

28. Emerson, Lynn A. Technician training beyond the high school - suggested procedures for planning preemployment programs. Raleigh, North Carolina, State Department of Public Instruction. 1962.

29. Faden, Arnold M. Elements of spatial economics. Unpublished Ph.D. thesis. New York, Library, Columbia University. 1967.

30. Forrester, Jay W. Industrial dynamics. Cambridge, Massachusetts, The M.I.T. Press. 1961.

31. Ginsberg, Eli. How men acquire skill. Employment Security Review 22: 33-37. 1955.

32. Hambleton, John W. Summer employment of youth. Employment and Earnings and Monthly Report on the Labor Force 15, No. 2: 6-10. 1968.

33. Hansen, W. Lee. Total and private rates of return to investment in schooling. Journal of Political Economy 71, No. 2: 128-140. 1963.

34. Harris, Seymor E., ed. Economic aspects of higher education. Paris, Study Group in the Economics of Education, Organization for Economic Co-operation and Development. 1964.

35. Hirsch, Werner Z. Spillover of public education: costs and benefits. Los Angeles, California, University of California Press. 1964.

36. Hirshleifer, Jack. On the theory of optimal investment decision. Journal of Political Economy 66, No. 4: 329-352. 1958.

37. Houthakker, H. S. Education and income. Review of Economics and Statistics 41, No. 1: 24-28. 1959.

38. Hunt, Shane. The economics of human resources by H. Correa: a review. The American Economic Review 54: 1187-1189. 1964.

39. Innes, Jon T., Paul B. Jacobson, and Ronald J. Peoegrin. The economic returns to education. Portland, Oregon, Center for the Advanced Study of Educational Administration, University of Oregon. 1965.

40. Iowa State Department of Public Instruction. Education beyond high-school age: the community college. Des Moines, Iowa, State of Iowa. 1962.

41. Iowa State Department of Public Instruction. Iowa public school data: 1966-67 school year. Department of Public Instruction Publication 768A-702AF. 1968.

42. Iowa State Department of Public Instruction. Iowa public school data: 1967-68 school year. Department of Public Instruction Publication 1068A-759AF. 1968.

43. Keezer, Dexter M. Financing higher education: 1960-1970. New York, McGraw-Hill Book Company. 1959.

44. Lind, R. C. The social rate of discount and the optimal rate of investment: further comment. The Quarterly Journal of Edonomics 78: 336-345. 1964.

45. Lombardi, John. Occupational education in California junior colleges. Educational Record 45: 142-147. 1964.

46. Machlup, Fritz. The production and distribution of knowledge in the United States. Princeton, New Jersey, Princeton University Press. 1962.

47. Marglin, S. A. The social rate of discount and the optimal rate of investment. The Quarterly Journal of Economics 77: 95-111. 1963.

48. Marglin, S. A. The social rate of public investment. The Quarterly Journal of Economics 77: 274-289. 1963.

49. Martin, Victor. Accelerated vocational training for adults: a comparative study: objectives, organizations, syllabuses, and methods, and future prospects. Paris, Organization for Economic Co-operation and Development. 1965.

50. Mesics, Emil A. Education and training for effective manpower utilization: an annotated bibliography. Bibliography Series No. 9. Ithaca, New York, New York State School of Industrial and Labor Relations, Cornell University. 1969.

51. McClure, William P. Educational cost analysis. Urbana, Illinois, University of Illinois. 1957.

52. Metropolitan Life Insurance Company. Statistical Bulletin, Vol. 48. 1967.

53. Miller, Herman P. Annual and lifetime income in relation to education: 1939-59. The American Economic Review 50: 962-986. 1960.

54. Miller, Robert W. Schedule, cost, and profit control with PERT, a comprehensive guide for program management. New York, McGraw-Hill Book Company. 1963.

55. Mincer, Jacob. On-the-job training: costs, returns, and some implications. The Journal of Political Economy 70, No. 5, Part 2: 50-79. 1962.

56. Mood, Alexander M. and Richard Powers. Cost-benefit analysis of education. National Center for Educational Statistics, Division of Operations Analysis, Office of Education, U.S. Department of Health, Education, and Welfare Technical Note N. 27. ca. 1960.

57. Morgan, James N. and C. Lininger. Education and income: comment. The Quarterly Journal of Economics 78: 346-347. 1964.

58. Morrison, Edward J. General vocational skills and the secondary curriculum. Unpublished mimeographed paper presented at the Conference on Research in Vocational and Technical Education, June, 1966. Washington, D.C., American Institutes for Research. ca. 1966.

59. Morsch, William C. A technique for projection of occupational-educational requirements for state educational planning areas. National Center for Educational Statistics, U.S. Department of Health, Education, and Welfare Technical Note No. 7. 1966.

60. Morsch, William C. Occupational education requirements analysis. Symposium paper. Mimeo. Washington, D.C., Office of Education, United States Department of Health, Education, and Welfare. ca. 1967.

61. Mushkin, Selma J. Health as an investment. The Journal of Political Economy 70, No. 5, Part 2: 129-157. 1962.

62. National Manpower Council. A policy for skilled manpower. New York, Columbia University Press. 1954.

63. Neverdahl, William J. A follow-up study of electronics technology students. Unpublished research paper. Menomonie, Wisconsin, Stout State University. 1966.

64. Organization for Economic Co-operation and Development, Study Group in the Economics of Education. Economic aspects of education. Paris, Organization for Economic Co-operation and Development. 1964.

65. Page, Andre'. Desirable balance between general education and technical and vocational training. In Robinson, E. A. G. and J. E. Vaizey. The economics of education. Pp. 497-515. New York, Saint Martin's Press. 1966.

66. Panes, Herbert S., ed. Planning for economic and social development. Washington, D.C., Organization for Economic Co-operation and Development. 1962.

67. Papi, G. U. General problems of the economics of education. In Robinson, E. A. G. and J. E. Vaizey. The economics of education. Pp. 3-23. New York, Saint Martin's Press. 1966.

68. Perlman, Mark, ed. Human resources in the urban economy. Washington, D.C., Resources for the Future. 1963.

69. Priest, A. R. and R. Turvey. Cost-benefit analysis: survey. The Economic Journal 75: 683-735. 1965.

70. Robinson, E. A. and J. E. Vaizey, eds. The economics of education. New York, Saint Martin's Press. 1966.

71. Schultz, T. W. The economic value of education. New York, Columbia University Press. 1963.

72. Schultz, T. W. Reflections on investment in man. The Journal of Political Economy 70, No. 5, Part 2: 1-8. 1962.

73. Shaffer, L. R., J. B. Ritter and W. L. Meyer. The critical-path method. New York, McGraw-Hill, Inc. 1965.

74. Sheats, Paul L. Occupational training and higher education. Educational Record 45: 139-141. 1964.

75. Sjaastad, Larry A. The costs and returns of human migration. The Journal of Political Economy 70, No. 5, Part 2: 80-93. 1962.

76. Soltow, L. The distribution of income related to changes in the distribution of education, age, and income. The Review of Economics and Statistics 42: 450-453. 1960.

77. Somers, Gerald G. Evaluation of work experience and training of older workers. Madison, Wisconsin, Industrial Relations Resrarch Institute, University of Wisconsin. 1967.

78. Spiegelman, Robert G., Martin Gorfinkel, Mordecai Kurz, and Samuel Weiner. A benefit/cost model to evaluate educational programs. Standord Research Institute Project 6179. 1968.

79. Stigler, George J. Information in the labor market. The Journal of Political Economy 70, No. 5, Part 2: 94-105. 1962.

80. Stires, David M. and Maurice M. Murphy. Modern management methods, PERT and CPM. Boston, Massachusetts, Materials Management Institute. 1962.

81. Thomas, Robert W., Trevor G. Howe, and James J. Mikesell. Collection of occupational data by skill clusters using a sampling technique. Final report, Project ERD 255, Contract N.O.E. 5-85-108, B.R. No. 5-0045, Research and development in vocational and technical education: non-metropolican areas; research reports. Appendix 2, Iowa State University, Ames, Iowa. Bureau of Research, Office of Education. U.S. Department of Health, Education, and Welfare. 1968.

82. Tinbergen, Jan, H. C. Bos, James Blum, Louis Emmerij, and Gareth Williams. Econometric models of education: some applications. Paris, Organization for Economic Co-operation and Development. 1965.

83. Tullock, G. The social rate of discount and the optimal rate of investment: comment. The Quarterly Journal of Economics 78: 331-336. 1964.

84. U.S. Bureau of the Census. Current population reports, annual mean income, lifetime income, and educational attainment of men in the United States, for selected years, 1956 to 1966. U.S. Bureau of the Census Series P-60, No. 56. 1968.

85. U.S. Bureau of the Census. Educational change in a generation. U.S. Bureau of the Census Series P-20, No. 132. 1962.

86. U.S. Bureau of the Census. Occupation by earnings and education, U.S. Census of Population, 1960. U.S. Bureau of the Census Publication PC (2)-7B. 1960.

87. U.S. Bureau of the Census. Present value of estimated lifetime earnings. U.S. Bureau of the Census Technical Paper No. 16. 1967.

88. U.S. Department of Health, Education, and Welfare, Vocational Rehabilitation Administration, Division of Statistics and Studies. An exploratory cost-benefits analysis of vocational rehabilitation. Washington, D.C., author. 1967.

89. U.S. Department of Labor, Bureau of Economic Security. Dictionary of occupational titles, 1965. Vol. 2. Third edition. Washington, D.C., author. 1965.

90. U.S. Department of Labor, Bureau of Labor Statistics. Employment and earning statistics for the United States, U.S. Dept. of Labor, Bureau of Labor Statistics Bul. 1312-4. 1967.

91. U.S. Department of Labor, Bureau of Labor Statistics. Injury rates by industry, 1964 and 1965. U.S. Dept. of Labor, Bureau of Labor Statistics Report 342. _ca_. 1969.

92. U.S. Department of Labor, Bureau of Labor Statistics. Wage chronology, Aluminum Company of America, 1939-67. U.S. Dept. of Labor, Bureau of Labor Statistics Bul. 1559. 1967.

93. Vaizey, John Ernest. The economics of education. New York, Free Press of Glencoe. 1962.

94. Vaizey, John Ernest and John Sheehan. Resources of education: an economic study of education in the United Kingdom, 1920-1965. London, Allen and Unwin. 1968.

95. VanDenHaag, Ernest. Education as an industry. New York, Augustus M. Kelley. 1956.

96. Weisbrod, Burton A. Education and investment in human capital. The Journal of Political Economy 70, No. 5, Part 2: 106-123. 1962.

97. Weisbrod, Burton A. Effect of non-quantifiable factors on individual income. Seminar presented at Iowa State University, April 4, 1968, based on an unpublished paper with Lee Hanson. Madison, Wisconsin, Dept. of Economics, University of Wisconsin. 1968.

98. Weisbrod, Burton A. External benefits of public education. Princeton, New Jersey, Industrial Relations Section, Princeton University. 1964.

99. Williams, Gertrude. Training for skill. Fabian Research Series No. 205. London, The Fabian Society. 1959.

100. Winklemann, Don. Cost of public education in Iowa. Iowa State University Cooperative Extension Service Special Report 44. 1965.

101. Wiseman, J. Cost-benefit analysis in education with comment by T. W. Schultz. The Southern Economic Journal 32, No. 1, Part 2: 1-14. 1965.

IX. ACKNOWLEDGEMENTS

Appreciation is extended to Professor Robert W. Thomas for his guidance and assistance in this study and throughout all phases of the graduate program. Thanks are also extended to Professors Lehman B. Fletcher, Trevor G. Howe, Neil E. Harl, and Ronald C. Powers for serving on the graduate committee.

Appreciation is also extended to Mrs. Velma Buttermore for her assistance in locating published materials and to my numerous colleagues for their helpful advice and criticism.

X. APPENDIX A. RELATIONSHIP OF EDUCATION AND PAYOFF

In the regressions of Tables A.1 and A.3 there are two different sets of dummy variables. The first set is level of formal education, and the second is previous work experience and level of vocational education. Previous work experience could not be separated from vocational education as any occupations which required both for entry were recorded as having the vocational training prerequisite, only. Thus, the intercept coefficients indicate the expected starting and top wages for individuals with an eighth grade education or less, and no previous work experience or vocational training. The following observations can be made from the results of the tables. While formal education shows fairly impressive payoffs in the metal trades the payoff from a high school degree is considerably less. The best indication is that a high school degree raises beginning pay by six to seven cents and top pay by about ten cents per hour. However, the top pay effect is significant at the .95, but not at the .99 level, while the starting pay figure is not significant at either level. The regression analysis estimates that a college degree increases the beginning pay by \$1.485 and the top pay by \$2.441, while "some college" increases beginning pay by \$.483 and top pay by \$1.107. These estimates are significantly different from zero at the .99 level. The $\hat{\beta}$-coefficients for vocational education, with the exception of less than six months, show that pay rates are an increasing function of the amount of vocational training in both the beginning and top wage categories. This analysis supports the investment assumption of the model and indicates the appropriateness of applying this survey data from Iowa

Table A.1. Multiple regression of education on starting wage

Source	$\hat{\beta}$	t-value
College degree	1.485	14.7708**
Some college	.483	8.6186**
High school degree	.065	1.9061
Some high school	.006	.1362
Previous work experience	.279	8.4526**
Vocational training		
less than 6 months	.277	4.0624**
6-12 months	.091	1.7065
12-18 months	.165	3.0331**
18-24 months	.404	7.2442**
more than 24 months	1.069	8.6176**
Intercept ($\hat{\beta}_o$)	2.354	84.0551**

**Significant at .99 level, here and in following tables.

Table A.2. ANOV of education on starting wage

Source	D.F.	Sum of squares	Mean square	F-ratio
Total	2165	996.331		
Regression	10	197.464	19.746	
Residual	2155	798.867	.371	53.2672

Table A.3. Multiple regression of education on top wage

Source	$\hat{\beta}$	t-value
College degree	2.441	17.6440**
Some college	1.107	14.9750**
High school diploma	.100	2.1844*
Some high school	-.112	-1.9314
Previous work experience	.389	8.8303**
Vocational training		
less than 6 months	.157	1.7154
6-12 months	.201	2.8584**
12-18 months	.341	4.7590**
18-24 months	.644	8.7590**
more than 24 months	1.220	7.5198**
Intercept (β_o)	2.830	75.9279**

*Significant at .95 level, here and in following tables.

Table A.4. ANOV of education on top wage

Source	D.F.	Sum of squares	Mean square	F-ratio
Total	2086	1886.397		
Regression	10	572.378	57.238	
Residual	2076	1314.019	.633	90.4292

metal trades to the model structure.

The regressions of Table A.5 are run across all occupations within each general education category. The intercept coefficient, $\hat{\beta}_0$, indicates the average starting wage for entrants with no vocational training. These entry wages are nearly the same for the three lower education groups, indicating that the direct marginal return to additional education, at this level, is quite small in metal occupations. The relationship of vocational training programs, of under 24 months in duration, to wages, appears to be inconclusive for education levels other than high school completion. The payoff from high school graduation then is gained from the combination of this education with the vocational education programs, to which it opens entry.

In all categories there is no indicated relationship of wages as an increasing function of time spent in vocational education. Several things might be suggested from this observation. Partially this is an indication that occupations within any general education category differ significantly in the relationship of vocational education and its expected payoff. Moreso, it reflects the problems encountered by making aggregations of data, disregarding one of the most important variables (i.e. occupation). It might also be suggested, particularly in the lower levels of general education, that those occupations requiring the least vocational training, are less desirable. Such occupations might be expected to require more brawn and less brains and be generally more displeasing jobs in which to work, and thus harder to fill, despite the lack of educational requirements.

Table A.5. Multiple regressions of vocational training entry requirements on starting hourly wage, by general education entry requirements

General education	$\hat{\beta}_o$	Vocational training 6 mo.	6-12 mo.	12-18 mo.	18-24 mo.	24 mo.
8th grade or less	2.46**	-.21	-.33	-.13	.84**	-
Standard error	(.0259)[a]	(.1354)	(.1844)	(.1751)	(.2087)	(-)
Some high school	2.47**	.16	-.09	.03	-.09	2.85**
Standard error	(.0310)	(.1453)	(.1267)	(.1350)	(.2220)	(.4926)
High school diploma	2.48**	.35**	.09	.12*	.36**	.82**
Standard error	(.0235)	(.0880)	(.0622)	(.0615)	(.0712)	(.1462)
Some college	3.02**	-1.02	-.26	-.39	.14	.97*
Standard Error	(.0838)	(.8292)	(.2437)	(.3783)	(.1409)	(.4209)
College diploma	4.01**	-3.01**	-.76	-.52	-	-
Standard error	(.1898)	(1.1230)	(1.1230)	(1.1230)	(-)	(-)

[a]Numbers in ( ) are standard errors of $\hat{\beta}$ values.

XI. APPENDIX B. DESCRIPTION OF OCCUPATIONAL ACTIVITIES

DOT classifications can be aggregated to broad categories by the first digit of their designation. These broad categories are:

0 - TECHNICAL OCCUPATIONS:
A technician is a worker who is on an educational level between a skilled tradesman and a professional scientist, or engineer. His technical knowledge permits him to assume some duties formerly assigned to the graduate engineer, or scientist. For example, technicians may design a mechanism, compute the cost, write the specifications, organize the production, and test the finished product (89, p. 23).

5 - PROCESSING OCCUPATIONS:
These occupations are concerned with refining, mixing, chemically treating, molding, casting, coating, or otherwise processing metals. These occupations include those concerned with covering surfaces by electrodeposition or electrolysis.

6 - MACHINE TRADES OCCUPATIONS:
Generally, occupations here deal with feeding, tending, operating, controlling, and setting up machines to work on raw materials. The relationship of the worker to the machine is important. Coordination of eye and hand are important. Repair, maintenance, and installation are important. Occupations are associated with shaping metal parts and products.

7. BENCH WORK OCCUPATIONS:
Occupations here are concerned with the use of body members to operate hand tools and bench machines. Occupations are concerned with fabricating, repairing, reconditioning, machine setting, blueprint reading, and following patterns using a variety of hand tools or bench machines.

8. STRUCTURAL WORK OCCUPATIONS:
These occupations are concerned with fabricating, erecting, installing, painting, and repairing working structures or parts of structures. Customarilly, these are workers dealing with outside-of-factory activities related to metals, glass, etc. These workers need to know materials and their stresses and strains. Think of fabricating, trestles, towers, bridges, drilling rigs, airframes, boilers, and storage tanks.

The specific descriptions of occupational activities, without regard to educational prerequisites, are presented in Table B.1.

Table B.1. Model classification, DOT classification, and description of occupational activities

Classification Model	DOT	Description
0031	003.181	Electrical Technician This technician is concerned with applying electrical theory and related subjects to test and modify developmental or operational electrical machinery and electrical control equipment and circuitry in industrial or commercial plants and laboratories.
0032	003.181	Electronic Technician This technician is associated with a computer laboratory or with instrumentation and development, or electronic communications, or with systems testing.
0070	007.181	Tool and Die Designer This is a highly skilled craft or trade in which general and special tools are planned and designed and their dies are created. These craftsmen are concerned with application of principles of physics and engineering in regard to utilization of heat and mechanical power for design and production of tools and machines. Specifically, these craftsmen might be concerned with power tools, instrumentation, or machine design.
0074	007.281	Draftsman, Mechanical This technician does drafting and lay-out work for castings, tool design, and related activities. The work of a mechanical draftsman is generally associated with drafting and lay-out for tool and machine production, such as a tool-design draftsman.
0012	012.288	Industrial Technician This technician studies and records time, motion, methods, and speed involved in performance of maintenance, production, clerical, and other worker operations to establish standard production rate and to improve efficiency.
503	503	Pickling, Cleaning, Degreasing, and Related Occupations Workers in this group have occupations concerned with cleaning metal objects (generally with an acid bath) to remove coatings of grease, scale, tarnish, oxide, etc. An example is a pickler operator.

Table B.1. (Continued)

Classification Model	DOT	Description
504	504	Heat-treating Occupations A worker here is concerned with subjecting metal to heat, cold, or chemicals to relieve or redistribute stresses and affect such characteristics as hardness, flexibility, and ductility. An example is a gear hardener.
514	514	Pouring and Casting Occupations This is a worker concerned with pouring, injecting, centrifuging, or pressing molten or powdered metal into a mold or other receptable and permitting it to solidify. An example is a metal pourer.
518	518	Molders, Coremakers, and Related Occupations This worker is concerned with making molds or cores to be used in casting metal in a foundry. An example is a mold maker.
519	519	Ore Refining and Foundry Occupations, n.e.c. This group of workers are in occupations not classified elsewhere, but concerned with refining ore, ore concentrate, pig, or scrap and casting metal in a foundry. An example is a foundry foreman.
600	600	Machinists and Related Occupations This worker is concerned with shaping metal parts by milling, turning, planing, abrading, boring, clipping, sawing, and shaving with a variety of metal tools, and includes laying-out, job setting, fitting, assembling, and repairing. An example is a machine repairman.
601	601	Toolmakers and Related Occupations This worker is concerned with the entire scope of construction, repairing, maintaining, and calibrating machine-shop tools, jigs, fixtures, instruments, and metal-forming dies. An example is a die maker.
603	603	Abrading Occupations A worker here is concerned with smoothing, polishing, or sharpening metal objects by the wearing-away action of abrasives or machine files. An example is a tool sharpener.

Table B.1. (Continued)

Classification Model	DOT	Description
604	604	<u>Turning Occupations</u> A worker here is concerned with shaping metal by the paring or chipping action of rigid cutting tools to metal rotating on a lathe. An example is an automatic-screw-machine operator.
605	605	<u>Milling and Planing Occupations</u> A worker here is concerned with removing excess metal by the action of a revolving multiple-tooth cutter, thus producing flat or profiled surfaces, grooves, and slots. An example is a milling-machine set-up operator.
606	606	<u>Boring Occupations</u> A worker here is concerned with piercing metal by means of rotary-cutting tools advanced into the material in the direction of the tool's axis to make, enlarge, or thread a hole. An example is a drill-press operator.
607	607	<u>Sawing Occupations</u> A worker here is concerned with severing or shaping metal with a saw-toothed or abrasive-edged blade or disk. An example is a sawing-machine operator.
609	609	<u>Metal Machining Occupations, n.e.c.</u> Workers in this group have occupations, not elsewhere classified, concerned with shaping metal parts or products by removing excess material from stock or objects. An example is a sheet-steel inspector, thread grinder.
615	615	<u>Punching and Shearing Occupations</u> A worker here is concerned with making holes in metal by cutting out a circular wad under pressure from a die whose hole is slightly larger than the diameter of the punch; and cutting or shearing metal by the action of a keen-edged cutting tool. An example is a punch-press operator.
616	616	<u>Fabricating Machine Operators</u> A worker here is concerned with shaping, fitting, and assembling metal parts. An example is a wire weaver, fabricating-machine operator.

Table B.1. (Continued)

Classification Model	DOT	Description
617	617	Forming Occupations, n.e.c. Workers here have occupations, not elsewhere classified, concerned with shaping metal by the application of machine pressure; an example being a hydraulic-press operator.
619	619	Miscellaneous Metalworking Occupations, n.e.c. Workers here have occupations, not elsewhere classified, concerned with shaping and conditioning metal by such means as rolling, forging, extruding, blanking, and pressworking. An example is a rolling foreman.
620	620	Motorized Vehicle and Engineering Equipment Mechanics and Repairmen A worker here is concerned with repairing gasoline and diesel-powered engines and accessories, other mechanical parts of motorized vehicles including materials-handling equipment. An example is a garage mechanic.
626	626	Metalworking Machinery Mechanics A worker here is concerned with repairing general purpose and specialized metal-cutting and metal-forming machines, accessories, and related equipment. An example is a hydraulic-press servicemen.
637	636	Utilities Service Mechanics and Repairmen A worker here is concerned with installing, maintaining, and repairing mechanical equipment and appliances used to supply heat, conditioned air, refrigeration, water, and related utilities. An example is an air-conditioning mechanic.
638	638	Miscellaneous Occupations in Machine Installation and Repair A worker here is concerned with machine installation and repair which has not been covered in other categories listed in this series of machine trades occupations. An example is a millwright.

703	703	<u>Occupations in Assembly and Repair of Sheet-metal Products, n.e.c.</u> Workers here have occupations, not elsewhere classified, concerned with laying-out, cutting, shaping, and fitting sheet metal to assemble or repair sheet metal parts and items, but these are not structural sheet metal workers. An example is a template cutter.
706	706	<u>Metal Unit Assemblers and Adjusters, n.e.c.</u> Workers here have occupations, not elsewhere classified, concerned with assembling and adjusting non-electrical metal units or components including mechanical assembling or adjusting not requiring overall mechanical knowledge. An example is a solderer-assembler.
709	709	<u>Miscellaneous Occupations in Fabrication, Assembly, and Repair of Metal Products, n.e.c.</u> Workers here have occupations, not elsewhere classified, concerned with fabricating, assembly, and repairing metal products. An example is a hand riveter, inspector.
741	741	<u>Painters, Spray</u> A worker here is concerned with covering or decorating surfaces, using spray guns and stencils. An example is an enamel sprayer.
801	801	<u>Fitting, Bolting, Screwing, and Related Occupations</u> A worker here is concerned with joining structural parts and components with bolts, screws, or related fasteners. An example is a compressor assembler.
809	809	<u>Miscellaneous Occupations in Metal Fabricating, n.e.c.</u> Workers here have occupations, not elsewhere classified, concerned with fabricating structures from metal and from related materials. An example is a sheet-metal-shop foreman.
810	810	<u>Arc Welders</u> A worker here is concerned with welding using electric welding equipment with current across an air gap between the workpiece and an electrode. An example is a multiple spot welder.
812	812	<u>Combination Arc Welders and Gas Welders</u> A worker here is concerned with welding, using gas and arc welding equipment. An example is a casting repair welder.

XII. APPENDIX C. EDUCATIONAL LOANS

The effect of educational loans on the present-value of activity paths containing that education activity was shown in Part C.1, of Chapter III. Table C.1, which is presented here, represents a situation where the loan is repaid in equal sized installments with the first payment period starting at the same time as the loan is taken out. The length of payoff period, interest rate on the loan, and personal discount rate are allowed to assume numerous values. No situations were considered where the loan rate was greater than or equal to the personal discount rate, for in such a situation the loan would present no advantage to the individual. The fractional units in the body of Table C.1 are the fractional part of an x-dollar loan which would be added to the present-value of the educational activity. The formula used is:

$$V_{ijk} = ((1 + r)^{(t_j + t_k)/2} / (t_j - t_k))\ (1 / (1 + r)^i - 1 / (1 + \rho)^i) \text{ where}$$

i = number of periods from time of loan to end of payments

t_j = number of last payoff periods

t_k = number of payoff periods until payments begin (in Table C.1, $t_j = 0$)

r = rate of interest on the loan

ρ = personal discount rate.

Table C.1. Addition to present-value of unit-value loan with initial payoff in first period, under various loan rates, personal discount rates, and lengths of payoff period

Loan rate	Personal discount rate	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
		Length of payoff period (years)								
0.00	0.05	.1341	.1540	.1734	.1921	.2102	.2278	.2449	.2614	.2774
	0.08	.2015	.2295	.2562	.2817	.3059	.3290	.3510	.3720	.3920
	0.15	.3296	.3693	.4057	.4391	.4698	.4981	.5242	.5483	.5705
0.01	0.05	.1074	.1236	.1393	.1546	.1694	.1839	.1979	.2116	.2249
	0.08	.1765	.2014	.2251	.2478	.2695	.2902	.3100	.3290	.3471
	0.15	.3078	.3453	.3798	.4116	.4409	.4680	.4930	.5161	.5376
0.02	0.05	.0807	.0930	.1050	.1167	.1281	.1392	.1501	.1607	.1710
	0.08	.1515	.1731	.1938	.2136	.2327	.2509	.2684	.2852	.3014
	0.15	.2861	.3214	.3539	.3840	.4119	.4376	.4615	.4838	.5044
0.03	0.05	.0539	.0622	.0703	.1783	.0861	.0937	.1012	.1085	.1157
	0.08	.1264	.1447	.1622	.1791	.1953	.2110	.2261	.2506	.2546
	0.15	.2643	.2974	.3279	.3563	.3826	.4070	.4299	.4511	.4709
0.04	0.05	.0270	.0312	.0353	.0394	.0434	.0473	.0512	.0550	.0588
	0.08	.1013	.1161	.1304	.1442	.1575	.1704	.1829	.1950	.2066
	0.15	.2426	.2733	.3018	.3284	.3531	.3762	.3978	.4180	.4370
0.05	0.08	.0761	.0874	.0983	.1089	.1191	.1291	.1388	.1482	.1574
	0.15	.2208	.2491	.2755	.3002	.3233	.3450	.3653	.3845	.4025
0.06	0.05	.0508	.0584	.0659	.0731	.0801	.0870	.0937	.1002	.1066
		.1990	.2249	.2491	.2718	.2932	.3133	.3323	.3503	.3673
0.07	0.08	.0255	.0293	.0331	.0368	.0404	.0440	.0474	.0509	.0542
	0.15	.1772	.2005	.2224	.2431	.2627	.2812	.2987	.3154	.3313
0.08	0.15	.1553	.1760	.1956	.2142	.2318	.2485	.2645	.2797	.2944
0.09	0.15	.1333	.1514	.1685	.1848	.2003	.2152	.2295	.2432	.2564
0.10	0.15	.1113	.1266	.1412	.1551	.1685	.1813	.1937	.2057	.2173

Table C.1. (Continued)

Loan rate	Personal discount rate	Length of payoff period (years) 14.0	15.0	16.0	17.0	18.0	19.0	20.0
0.00	0.05	.2929	.3080	.3226	.3368	.3506	.3639	.3769
	0.08	.4111	.4294	.4468	.4634	.4793	.4945	.5091
	0.15	.5911	.6102	.6279	.6443	.6596	.6738	.6870
0.01	0.05	.2378	.2504	.2626	.2745	.2861	.2974	.3084
	0.08	.3645	.3811	.3970	.4123	.4269	.4410	.4544
	0.15	.5575	.5759	.5931	.6091	.6240	.6380	.6510
0.02	0.05	.1811	.1910	.2006	.2101	.2193	.2283	.2370
	0.08	.3169	.3318	.3461	.3599	.3731	.3859	.3982
	0.15	.5236	.5415	.5583	.5739	.5885	.6022	.6151
0.03	0.05	.1228	.1297	.1364	.1431	.1496	.1560	.1623
	0.08	.2681	.2811	.2937	.3059	.3176	.3290	.3400
	0.15	.4895	.5068	.5231	.5384	.5528	.5663	.5791
0.04	0.05	.0625	.0661	.0697	.0732	.0767	.0801	.0835
	0.08	.2180	.2289	.2396	.2499	.2599	.2697	.2792
	0.15	.4548	.4716	.4874	.5023	.5164	.5298	.5426
0.05	0.08	.1663	.1750	.1834	.1917	.1998	.2076	.2153
	0.15	.4195	.4357	.4510	.4655	.4793	.4925	.5052
0.06	0.08	.1129	.1190	.1250	.1309	.1366	.1423	.1479
	0.15	.3835	.3989	.4136	.4276	.4411	.4541	.4666
0.07	0.08	.0575	.0607	.0639	.0671	.0702	.0733	.0763
	0.15	.3465	.3611	.3750	.3885	.4015	.4141	.4263
0.08	0.15	.3085	.3220	.3351	.3479	.3603	.3723	.3842
0.09	0.15	.2692	.2816	.2937	.3055	.3171	.3284	.3396
0.10	0.15	.2286	.2396	.2505	.2611	.2716	.2820	.2923

XIII. APPENDIX D. ACTIVITY INPUT DATA

Table D.1 and Table D.2 present the parameters of the activities used in the applied model, including their linkages through events. Table D.1 presents the parameters for the occupational activities. The column headings in Table D.1 are:

IDENT = identification number of the activity

EDUC = level of education required for occupation entry, where:
1 = eighth grade, or less
2 = some high school
3 = high school graduation
4 = some college

EWAGE = entry wage, per month

TWAGE = top wage, per month (as identified in the Iowa metal-trades survey)

VT = months of vocational education required for occupation entry

PREC = identification number of the preceding event

SUC = identification number of the succeeding event.

In Table D.2, which presents the parameters for education activities, the same definitions hold, except those for EWAGE and TWAGE. These new definitions are:

EWAGE = personal cost, per month

TWAGE = social cost, per month.

Table D.1. Occupational data

IDENT	EDUC	VT	EWAGE	TWAGE	PREC	SUC
311	1	0.0	523.97	573.31	1	1000
5031	1	0.0	413.05	446.75	1	1000
5041	1	0.0	553.45	561.32	1	1000
5141	1	0.0	454.83	528.67	1	1000
5181	1	0.0	487.45	566.60	1	1000
5191	1	0.0	483.21	534.16	1	1000
6001	1	0.0	439.26	532.30	1	1000
6031	1	0.0	424.78	491.94	1	1000
6041	1	0.0	514.01	562.71	1	1000
6061	1	0.0	401.49	464.08	1	1000
6091	1	0.0	448.16	508.59	1	1000
6151	1	0.0	417.91	514.18	1	1000
6171	1	0.0	411.02	460.17	1	1000
6191	1	0.0	352.39	533.30	1	1000
6381	1	0.0	527.43	605.14	1	1000
7031	1	0.0	333.41	436.84	1	1000
7061	1	0.0	367.99	403.55	1	1000
7091	1	0.0	388.26	501.29	1	1000
7411	1	0.0	441.96	506.23	1	1000
8011	1	0.0	442.79	514.50	1	1000
8101	1	0.0	370.45	530.12	1	1000
8102	1	8.30	415.29	530.12	101	1000
8121	1	0.0	439.04	504.50	1	1000

Table D.1. (Continued)

IDENT	EDUC	VT	EWAGE	TWAGE	PREC	SUC
8122	1	9.78	440.26	530.42	102	1000
6001	2	0.0	435.22	544.38	2	1000
6002	2	14.95	592.69	616.84	201	1000
6041	2	0.0	397.71	414.78	2	1000
6042	2	9.95	440.03	499.29	202	1000
6061	2	0.05	453.79	495.11	203	1000
6151	2	0.10	365.65	423.10	204	1000
6381	2	0.0	569.41	603.92	2	1000
7061	2	0.0	372.20	463.53	2	1000
7091	2	0.0	396.92	452.14	2	1000
7411	2	0.0	433.80	478.73	2	1000
8011	2	0.0	406.38	434.26	2	1000
8101	2	0.0	412.38	476.17	2	1000
8102	2	4.45	453.99	513.42	205	1000
311	3	0.0	567.37	638.45	3	1000
312	3	16.93	446.52	718.38	301	1000
321	3	20.50	540.56	848.45	302	1000
741	3	0.33	492.56	714.07	307	1000
742	3	16.65	465.84	829.21	308	1000
121	3	4.60	516.39	738.31	309	1000
5141	3	0.0	397.92	481.53	3	1000
5181	3	0.0	386.50	446.76	3	1000
6001	3	2.36	451.89	535.52	303	1000

Table D.1. (Continued)

IDENT	EDUC	VT	EWAGE	TWAGE	PREC	SUC
6002	3	22.00	465.17	611.93	304	1000
6011	3	0.0	522.36	632.08	3	1000
6012	3	14.16	592.34	654.02	305	1000
6013	3	22.02	592.34	729.84	306	1000
6041	3	0.0	360.47	484.50	3	1000
6042	3	9.80	508.40	547.37	310	1000
6051	3	0.0	407.21	569.05	3	1000
6052	3	10.20	526.69	579.17	311	1000
6061	3	0.0	445.21	527.50	3	1000
6062	3	8.98	501.11	530.29	312	1000
6071	3	0.0	386.83	477.36	3	1000
6072	3	12.64	481.96	553.97	313	1000
6091	3	0.0	364.22	422.59	3	1000
6092	3	5.05	485.44	567.84	314	1000
6151	3	0.0	403.33	474.12	3	1000
6152	3	9.48	485.48	568.99	315	1000
6161	3	0.0	360.24	458.96	3	1000
6162	3	4.62	515.84	559.50	316	1000
6171	3	0.78	436.84	509.14	317	1000
6201	3	5.63	538.12	635.23	318	1000
6261	3	0.0	483.75	559.88	3	1000
6262	3	10.71	530.12	637.81	319	1000
6371	3	0.0	552.26	592.66	3	1000

Table D.2. Educational data

IDENT	EDUC	VT	EWAGE	TWAGE	PREC	SUC
6372	3	16.64	541.87	643.80	320	1000
6381	3	0.0	428.77	524.18	3	1000
6382	3	14.71	540.24	608.53	321	1000
7031	3	0.0	500.67	574.71	3	1000
7032	3	29.02	500.67	814.42	322	1000
7061	3	0.0	413.62	468.09	3	1000
7091	3	0.0	424.03	500.77	3	1000
7092	3	5.46	424.03	554.84	323	1000
7411	3	0.0	421.05	467.56	3	1000
7412	3	5.35	531.39	570.38	324	1000
8011	3	0.42	498.68	550.80	325	1000
8091	3	0.42	375.64	458.71	326	1000
8101	3	0.0	398.60	469.41	3	1000
8102	3	7.41	493.33	552.55	327	1000
8121	3	0.0	537.32	562.74	3	1000
8122	3	9.15	537.32	600.95	328	1000
121	4	4.50	544.98	871.63	402	1000
701	4	17.39	734.54	842.68	401	1000
741	4	12.92	434.77	629.95	403	1000
742	4	21.00	455.55	728.98	404	1000

Table D.2. (Continued)

IDENT	EWAGE	TWAGE	TIME	PREC	SUC
9002	8.33	37.90	24.00	1	2
9101	125.00	181.51	8.30	1	101
9102	125.00	181.51	9.78	1	102
9003	-25.00	21.25	24.00	2	3
9201	125.00	158.58	14.95	2	201
9202	125.00	158.58	9.95	2	202
9203	125.00	158.58	0.05	2	203
9204	125.00	158.58	0.10	2	204
9205	125.00	181.51	4.45	2	205
9004	0.0	9.00	24.00	3	4
9301	125.00	126.59	16.93	3	301
9302	125.00	126.59	20.50	3	302
9303	125.00	158.58	2.36	3	303
9304	125.00	158.58	19.64	303	304
9305	125.00	158.58	14.16	3	305
9306	125.00	158.58	7.86	305	306
9307	125.00	128.33	0.33	3	307
9308	125.00	128.33	16.32	307	308
9309	125.00	158.58	4.60	3	309
9310	125.00	158.58	9.80	3	310
9311	125.00	158.58	10.20	3	311

Table D.2. (Continued)

IDENT	EWAGE	TWAGE	TIME	PREC	SUC
9312	125.00	158.58	8.98	3	312
9313	125.00	158.58	12.64	3	313
9314	125.00	158.58	5.05	3	314
9315	125.00	158.58	9.48	3	315
9316	125.00	158.58	4.62	3	316
9317	125.00	158.58	0.78	3	317
9318	125.00	158.58	5.63	3	318
9319	125.00	158.58	10.71	3	319
9320	125.00	141.84	16.64	3	320
9321	125.00	158.58	14.71	3	321
9322	125.00	158.58	29.02	3	322
9323	125.00	158.58	5.46	3	323
9324	125.00	158.58	5.35	3	324
9325	125.00	158.58	0.42	3	325
9326	125.00	158.58	0.42	3	326
9327	125.00	181.51	7.41	3	327
9328	125.00	181.51	9.15	3	328
9401	125.00	128.33	17.39	4	401
9402	125.00	193.80	4.50	4	402
9403	125.00	128.33	12.92	4	403
9404	125.00	128.33	8.08	403	404