DOCUMENT RESUME

ED 053 317 VT 013 613

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TITLE	Identifying Inputs Toward Production Function Application in Education.
INSTITUTION	Minnesota Research Coordinating Unit in Occupational Education, Minneapolis.
REPORT NO	TR-4
PUB DATE	Apr 71
NOTE	23p.
EDRS PRICE	EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS	Cost Effectiveness, *Educational Accountability, *Educational Economics, Educational Programs, Educational Research, Evaluation Needs, *Input Output Analysis, *Mathematical Models, Multiple Regression Analysis, Program Effectiveness, *Resource Allocations

ABSTRACT

Production function applications to improve the efficiency of educational programs require identification of inputs and outputs and the establishment of a data bank to provide information on input and output variables. This generalizable input identification model organizes inputs for systems analysis at various levels of inputs and provides a framework for isolating relevant from nonrelevant inputs. The precise measures of inputs and outputs which are required for ideal implementation of this multiple linear regression model are not feasible. However, the model can be implemented without full identification of variables. Model implementation will indicate which revisions are needed. (BH)

IDENTIFYING INPUTS TOWARD PRODUCTION FUNCTION APPLICATION IN EDUCATION

George H. Copa

As early as 1963, a committee report of the House of Representatives (1) concluded that committee members suffer from "the inadequate and misleading nature of available educational statistics" and that "inconsistencies and even contradictions have arisen in our educational activities" (p. VI). Since that time, our educational activities have increased substantially with little change in the educational statistics used to manage them.

Proper management and justification of resource use requires effectiveness and efficiency information. Educational effectiveness refers to how well educational objectives are being achieved; efficiency refers to how economically they are being accomplished. If an educational system is viewed as a production unit with inputs moving through a change process resulting in identifiable outputs, the major inadequacy of present educational statistics is that they describe only the inputs or outputs rather than the relationship between the two. Effectiveness and efficiency decisions require relational information about inputs and outputs. This inadequacy is evident in the usual educational statistics reported, such as enrollment, promotions, graduates, pupil/teacher ratio and per pupil expenditure.

The characteristic of measuring only inputs or outputs makes these statistics descriptive at best. They may indicate that change is necessary but are useless in diagnosing the cause and prescribing the remedy.

Educational managers, therefore, remain in need of information which is prerequisite to well-grounded decision making. The production function, a concept common to economics and engineering but new to education, is one method of formulating the required information. This method requires identification of inputs and outputs of a given process. It then defines the relationship between these inputs and outputs and assesses the relationship between the inputs themselves. It has the potential to provide information which can be used to objectively diagnose and prescribe in decision making. This is the information essential to educators if they are to effectively and efficiently utilize their present resources and justify the need for additional resources.

PROBLEM DELIMITED

The production function of education should define and communicate the technical production constraints which are imposed on economic decisions made in the management of education. As an "in depth" approach to providing this information for education, it is still at an introductory state. This is expecially true at the micro level of application where it is necessary to define and interpret more aggregate relationships.

For the purpose of this report, an educational system is defined as an educational activity with identifiable inputs and outputs. It is assumed to be part of a larger structure and require management decisions within the activity itself and between activities of the same type.

Before production function applications for a given educational system can proceed and reach its full value, two problems must be solved.

1. Inputs and outputs for the given educational system must be identified in a quantifiable form.

2. A data bank must be established to provide information on the input and output variables as defined.

The identification and measurement of inputs and outputs of a given educational system must be considered an iterative process. Approximations to complete identification and precise measurement of the real inputs and outputs should result from a study of the relationships between inputs and outputs and among outputs themselves. The validity and reliability of identification and measurement can be assessed only if, in fact, these activities are on-going.

The second problem in production function formulation is that data must be gathered on the inputs and outputs as identified and measured. A characteristic of any information system is that it consumes as well as produces information. Most times the former process is of larger scale. The processes of identifying and measuring inputs and outputs and formulating a data bank are very inter-related. Complete identification requires complete information; complete information requires complete identification. These two processes are truly iterative in nature.

Although not necessary for production function formulation, the problem of a monitary accounting system for the output and input as identified must be explored. This system is necessary to obtain maximum return from the production function approach since cost, as well as benefit (output), information is prerequisite for decisions about efficiency.

Researchers and practitioners in education must become cognizant of the value of "learning by doing" in solving these problems towards production function application if effectiveness and efficiency criteria are to be realistically used in evaluating education's productivity. At the aggregate level, some research has already been completed and will be summarized in the review of literature which follows. However, at the more micro level of educational system, little in the way of a structured, inferential approach has even been attempted.

The major purpose of this report is to deal with the problems of identifying educational system inputs. This does not subjugate the problem of identifying educational systems outputs nor imply that inputs should be considered before outputs.

As with other productive processes, education uses inputs to produce outputs and, thereby, achieve production objectives. Production objectives should indicate output measures which can be used as valid gauges of production. When considering production function development, the other measures needed are of the inputs. The objective of this report is to describe a generalizable model for identifying educational system inputs. Only after conceptualizing such a model can the iterative problem of accumulating a data bank be fully elaborated and pursued.

IMPLICATIONS FOR EDUCATION

Given the premises that (a) financial resources for education will be more difficult to obtain in the future, and (b) education will have to use its allocated resources more efficiently to meet its needs, then the input identification model has implication for education.

The relevance of this model to education in general is in two forms. First, it provides one methodology for attacking the problem of identifying program inputs as a step toward production function construction. Although specific inputs may be different among various educational systems, the method is potentially generalizable. Second, the model will add to a relatively new body of knowledge entitled "the economics of education". Specifically, it will respond to the call for new research on the formulation and application of the production function in education at the micro level.

REVIEW OF LITERATURE

In order to provide a more structured approach to the relevant literature, the review is divided into two parts: (a) status of production function utilization in education, and (b) educational system input measurement.

Status of Production Function Use in Education

Vaizey (2) was one of the first to call for research to "determine the nature of the production function of education" (p. 86). He maintained that present production functions for education, however implicit they may be, were often socially rather than technically determined. In this context, he condemned the "value of inputs" as a means of assessing change in productivity in education without knowledge of the "value of the output".

Correa (3) presented a theoretical discussion of the production function in human resources development. He defined the production function of education as the "relationship which exists between the volume of education required by students and the time, intensity, and quality of the educational inputs" (p. 92).

Two levels of production function were proposed by Correa - the micro level which was exemplified by the learning curve for a specific skill or subject and the macro level which was aggregated over various educational institutions for a given social group. He viewed the production function as having immediate use in applying to education the systems now known for optimum allocation of scarce resources.

Tinbergen and Bos (4) and Thonstad (5) used models similar to Correa's aggregate production function as a method of educational planning on a national basis. Their models emphasized quantitative rather than qualitative measures of inputs and outputs. These models were used in long-term planning as a means of balancing education's production with national manpower requirements.

At a less micro level, Welch (6) used a production function framework to search for factors affecting quality of schooling. His quality measures were total current expenditures per pupil, instructional staff per 100 pupils, average salary for instructional staff, and number of pupils enrolled per secondary school. He sampled rural farm males, twenty-five years of age or older, who earned an income in 1959. The sample was taken from fifty-seven states (ten of the southern states were divided into white and non-white states). He stated there was strong evidence that the "most important determinants of differences in the quality of schooling were: (1) teaching quality as reflected in salaries, (2) the size of secondary school" (p. 380). However, Welch admitted that the analytical procedures he used were for searching rather than testing; therefore, no probability statements could be made about his results. He called for a less aggregative analysis to provide insight into unanswered issues.

Katzman (7) constructed several production functions of education in studying the distribution of education as a service through 56 elementary school districts in Boston. He viewed the school as an "input-output system in which educational resources interact with students to produce some change in student behavior" (p. 204). Multiple regression was used to construct production functions by regressing measures of output against school inputs and socio-economic status of district residents.

The input measures used by Katzman were: (a) percentage of students in crowded classrooms, (b) student-staff ratio, (c) percentage of teachers with permanent status, (d) percentage of teachers with master's degrees or better, (e) percentage of teachers with one to ten year's experience, (f) percentage of annual teacher turnover, and (g) district enrollment or scale. The output measures were (a) attendance rate, (b) membership rate, (c) continuation or non-dropout rate, (d) percentage of sixth graders taking and passing the examination to enter the elite Latin High School, and (e) median gains in reading achievement from the second to the sixth grades. His use of the production function framework in studying these big city elementary school systems resulted in information on the relative impact of various inputs on output measures. It also resulted in information on the productive efficiency of the total system by a comparison of marginal costs and marginal productivity of various inputs.

Kittleson (8) noted that immediate use of the production function model in education was to "provide a theoretical framework for systematically determining which variables really play an important role in the education process" (p. 48). He provided a theoretical production function model which could be used to study the input-output relationships at various levels of education. Provisions were made for consideration of input quality as a factor affecting output.

Moss and others (9) used the production function approach in developing a state-operated evaluation system for vocational education programs. This approach was used "in order to 'adjust' outcomes to insure 'fair' comparisons between substitutable programs, and to permit program diagnosis and subsequent improvement" (p. 50). They divided their inputs into program characteristics, which were variables controllable by program operators and developers, and constraint factors which were not controllable by this same group. Program outputs were categorized into program outcomes and intermediate outcomes. Program outcomes were the result of all program characteristics and constraint factors while intermediate outcomes were the results of only part of the inputs. They resolved that only the program outcomes should be used in evaluating the effectiveness and efficiency of a total vocational program.

The literature reviewed thus far represents the limited utilization to which the production function concept has been given in education. Other applications have been made but, in general, they follow the same patterns reviewed above. Although limited, these studies exemplify the potential of the production function to supply information which relates inputs to outputs.

Each of the studies reviewed, however, lacks a comprehensive method of identifying educational inputs. Lack of consideration of all inputs to the educational process being studied could lead to serious misinterpretation of findings. The next section of the review of literature deals more specifically with the problem of input identification.

Educational System Input Measurement

Theoretically, a production function can be constructed for any process as soon as inputs and outputs are specified and an adequate data base concerning them is established. For some industrial processes, with specific inputs and outputs, this may be a relatively simple task. However, for other industrial processes, as well as for education, the task of specifying inputs and outputs is much more difficult.

Woodhall and Blaug (10), in a study dealing with productivity measurement of British secondary education, provided a justification for evaluating the productivity of education. For them, productivity was a ratio of outputs produced to inputs used. They argued that an activity need not be profit making in order to use productivity as a measure of its efficiency. If the activity had specific objectives it wishes to attain, then productivity measurement should be in terms of those objectives. Education, like any business activity, has the problem of using scarce resources to maximize its effectiveness in attaining objectives. They pointed out that many educators fear economic productivity indices for education because they may be based on only quantity rather than both quantity and quality measures on inputs and outputs. It was reasoned that this fear was based on a thesis that measures of quality do not exist. However, the authors argued that for educators to deny measures of their output was to admit that they had no way of judging their success at attaining their objectives. If a more realistic interpretation of the situation was made, they stated "the dispute between economists and educators is not about whether it is possible to measure productivity, but about the validity of different measures" (p. 4).

Several attempts have been made at quantifying the inputs and analyzing impact on output at certain levels of education but their results have been meager in terms of information for decision making. Clark (11) defined input as "that which is spent in time, money, and energy to create a product" and output as "the product itself, and, in the case of education is the student and his knowledge" (p. viii).

On a theoretical basis, Correa (3) stated that the inputs into an educational program were numbers of students and certain costs. These costs were divided into consumer costs and supplier costs. The consumer costs were those paid by the student and were made up of tuition, books and supplies, and foregone income. The supplier costs were those paid by society and include capital and personnel.

Stone (12), with the same economic perspective, listed inputs into education as being intermediate (supplies), capital (buildings and equipment), and labor (teachers and administrators). He maintained that the use of these inputs depended on the activity level and technology of an education program. Activity level referred to the number of students flowing through the program; technology referred to the input-output relationship inherent in the educational program.

Davis (13), Lave (14), and Wilbur (15) theorized about the input-output relationship in education. Davis described the needs of the educational planner as being adequate descriptive and analytical constructs and a data base. He maintained that the data base should contain information on the demand vector (for education's output), the resource vector, and the input-output relationship between the two. Wilbur developed a model with instrumental and pupil inputs leading to quantitative and qualitative outputs. Instrumental inputs consist of money, organizational patterns, and staffing characteristics. Both Davis and Wilbur pointed out that education had both an evaluation criteria and data-gathering problem.

Wasserman (16) discussed educational inputs as a prelude to constructing price and quantity indices for education. He stated that "personnel services account for between 80 and 90 percent of disbursements for current expenses in public school systems . . . teachers alone account for about 2/3 of all expenditures" (p. 27). He discussed the pricing of educational inputs in terms of quantity but provided little consideration of quality of these inputs. Mathematical programming procedures were explored as a method of computing price indices; however, the approach was constrained by the limited knowledge about the relationship between educational inputs and educational returns or outputs.

The review of literature thus far has dealt largely with the theoretical aspects of input measurement in education. Following is a review of several studies with more analytical orientation involving the actual measurement of inputs and outputs in education.

The major objective of Goodman's (17) The Quality Measurement Project was "to develop techniques for assessing the quality of education provided by a school system and to put into the hands of school administrators effective procedures for identifying areas in which improvement may reasonably be expected given their own local conditions" (p. 71). The sample was ninety-seven school systems in the state of New York. The major output measure was achievement as measured by a battery of tests.

He hypothesized that if differences in output were found in systems which were similar on other characteristics, then the best system would set an achievable standard for the other systems. This was referred to as the "bootstrap pulling" technique of improving a school system.

School systems were grouped on the basis of institutional potential as a means of controlling for characteristics over which the school had no control. The measures used for grouping were population of school's area, location to large city, and the occupation of the student's parents; these measures were to represent socio-economic characteristics.

Goodman found a significant difference in output -- both between and within groups. He interpreted the between group difference to imply that the input factors over which the school had no control, help to explain output differences among systems. The within groups difference was taken to mean "what schools in similar settings do with pupils has a demonstratable effect upon pupil outcomes" (p. 35). The findings of within group differences was stated as being essential to the hope of improving pupil outcomes by assessing program quality. The relationship between output and inputs in terms of school practices in elementary and junior high, per pupil expenditure for institutional purposes, special staff per 1,000 students, and percent of teachers with five or more years of training were also studied. He concluded that school system output could be quantified but that "more pure" measures of input were needed.

Flanagan and others (18) in Studies of the American High School, a part of Project TALENT, studied 1353 American high schools. Working from a premise that it was "not possible to make meaningful comparisons of outcomes in schools unless the important situational factors are known and considered" (p. 1-9), they grouped schools on the basis of region, size of town, and quality of housing. One of the questions which they hoped to answer was, "What is the amount of benefit for a given amount of treatment under standardized conditions and subjects?" (p. 1-9). For them, an important criterion for educational decisions was cost per unit of gain achieved.

About 1,000 items of information were collected on schools, their students and staff, and the community in which they were located. Multiple correlational and regressional techniques were used in the analysis. In many cases, the variables were expressed as means for the schools. The major outcome measures were achievement, percent going on to college, and percent staying in school. The four most important variables in predicting these outputs were teacher salaries, amount of teacher's experience, number of books in school library and per pupil expenditure. Those variables listed as being unlikely to be important causes of these outputs were school size, average size of class, age of building, and suburban location. A major conclusion was "educational outcomes associated with a school are much more related to the quality and type of student it serves than to the size of the school or most of its specific educational policies or practices" (p. 11-15).

In the study by Coleman and others (19), entitled the Equality of Educational Opportunity, one of the questions asked was, "What is it about schools that has most effect upon the results they produce?" (p. 36). An introductory remark was that statistical evidence on the environment in which a child lives was meager because the quantified measures miss many relevant factors. This conclusion was based on the statements that the actual factors, which were most important in terms of school outcomes, may vary between schools and between children within schools, and, "the child experiences his environment as a whole, while statistical measures necessarily fragment it" (p. 37).

They collected information from 4,000 schools in the United States. Schools were grouped on a racial and geographic basis. A major finding, using a verbal ability test as a measure of achievement, was "only about 10-20 percent of the total variation in achievement for the groups that are numerically most important lies between different schools" (p. 296). Three possible sources of school to school variation in achievement were proposed: school factors, family background factors, and factors outside the school and family.

The percent of school-to-school variance accounted for by measured student background factors varied from 2 to 32 percent for various groups and grade levels (p. 299). Of the school factors measured, facilities and curriculum accounted for relatively little variation in achievement; teacher quality and educational background and aspirations of other students in the school as other school factors showed a stronger relationship to pupil achievement. Of the characteristics of the teacher which were measured, his verbal skills and the educational attainment of both him and his parents showed the highest relationship to pupil achievement.

Eninger and others (20), in the study The Process and Product of Technical and Industrial High School Vocational Education in the United States, portrayed the vocational education equation as being "vocational outcomes experienced by the vocational graduates are the interaction product of school, student, and occupational opportunity variables" (p. 12-2). For them, the key vocational outcome criterion variable was the relatedness of the first full-time job to the occupation studied.

They used a stratified sample of one hundred secondary schools in the United States from the population of 667 schools offering three or more technical and industrial courses. The sample was stratified on the basis of geographic region, total school enrollment, and type of school. Correlation was used to assess the contribution of school and student input variables to account for variation in outcome criteria.

Eninger had difficulty in deciding if the input and criterion variables should be described on a school (as means) or individual student basis. The second choice meant using replicated values of school variables. It was decided to express variables on a school basis because it simplified the procedure although it collapsed the range of scores on student resource variables.

Input information was collected on seventy variables. Because of a sample size of only one hundred, the input variables were organized into nine groups with the objective being to establish a priority rationale for improvements in a given group. The groups were placement related, teacher related, curriculum related, student resource, guidance related, instruction related, general facility, miscellaneous general, and shop facilities. Eninger concluded that the most fruitful areas for school improvement are school placement service and percentage of recommendable graduates.

The Educational Production Process: A Study of Measures of Quality in New Jersey High School Districts was the title of a study by Musgrave (21). He defined the educational productive process as one which "takes students of varying socio-economic backgrounds and develops a product in the form of graduates" (p. ii). The problem he studied was the development of educational output measures and the explanation of variation in output between districts.

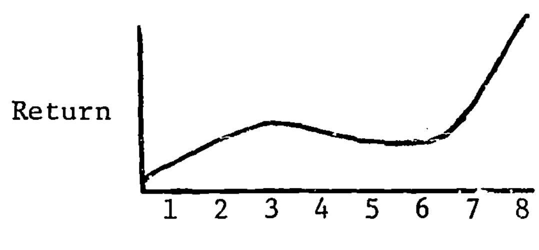
Output measures developed were potential earnings' value for graduating students and percentage of graduates going on to college. The variables defined as being useful in explaining the variation in output between school districts were divided into socio-economic factors and educational factors. The educational factors were current expense per pupil, teacher salaries per pupil, average number of years of teaching, total expenditure per weighted pupil, professional staff per one thousand weighted students, expenditures for library and audio-visual equipment per pupil, and school enrollment.

Using regression analysis, he found that the important variables affecting earnings' value were the district's socio-economic factors of racial composition and percentage of white collar workers and the educational factor of school enrollment. Cost-effectiveness analyses were also performed for increases in the educational factors. His general conclusion was "total expenditures on pupils are poor predictors of the selected measures of output" (p. iii).

Persons and others (22), in An Economic Study of the Investment Effects of Education in Agriculture, studied the economic returns to investment of communities and participants in the farm management program in Minnesota. Farm records for participants in the farm management instructional program were studied over an eight-year period. A benefit-cost analysis for the farm management participant and the local community was completed.

Another section of the study dealt with identifying those variables which account for variation in the farm income of participants. The measures of income were total farm sales, labor earnings, and returns to capital and family labor. As an example of the results, the independent variables which accounted for a significant portion of the variance at the .01 level in multiple regression analysis using a dependent variable of labor earnings, were (a) record number (number of years that a farmer had his records analyzed through farm management program), (b) total farm capital, (c) value of work off farm, (d) index of crop yield, (e) work units on livestock, and (f) efficiency factors above average. Similar analyses were conducted for total farm sales and returns to capital and family labor.

A third section of the study explained the formulation and implication of performance curves for the farm management instructional program. These curves were constructed using curvilinear regression; they represented the relationship between income measures and years of instruction. Their general form was:



The shape of the performance curve "shows a rising return to educational inputs during the first years, a decline during the fourth and fifth years, and a sharply rising slope beginning with the sixth and seventh year of the instructional program" (p. 3). The authors speculated that the shape of the curve was in response to the "learning curve" phenomenon and the nature of instruction.

The six studies which have been reviewed above represent a more analytical attempt to define and measure the inputs and outputs of an educational system as well as their relationships. These studies were conducted at four different levels or aggregations of the educational system. Goodman, Flanagan, Coleman, and Musgrave studied the school as a sampling unit. Eninger studied the program level. Persons studied the course and individual levels.

The conclusions which appeared warranted from these studies were: a) a common method or rationale for identifying educational system inputs was not being used, b) there was very little agreement as to which inputs were important between levels of education and between systems having different objectives, c) the appropriateness of a given measure of output for a particular educational system appeared to depend largely on the educational objectives of that system (as perceived by the study's author), and d) although they all introduce their studies by posing questions about the information needed to make management decisions, their summaries were at least partially lacking this information. They have, however, made a necessary start in the iterative process of identifying inputs and outputs at particular levels of education; their results serve as motivation for new research directed toward even closer approximations to complete identification.

Summary

The first section of the review of literature dealt with present theory and application of the production function in education. Use of the production function framework showed potential as a method of providing new educational statistics which are capable of relating inputs to outputs; however, one of the limits to its further application and usefulness appeared to be lack of a method of comprehensively identifying the inputs for an educational system.

The second section of the review assessed the status of educational input definition and measurement. A major need identified was for a common method of identifying inputs between educational system levels (e.g. course, program, school, state) and between educational systems with different objectives. A common methodology would maximize interpretability and comparability when analyzing systems varying in level or objectives. This report attempts to meet this need by introducing a model which can be used to identify important educational system inputs and which is potentially generalizable between educational systems.

INPUT IDENTIFICATION MODEL

The objective of the input identification model is to identify inputs of an educational system which are important determinants of the system's output. The model is directed at identifying inputs toward application of production function theory at specific educational system levels.

The input identification model is conceptually a model of an educational system. The educational system is viewed as an open system having three components - input, process, and output. This system is generalizable among educational systems varying in aggregation and objectives.

Referring to Figure 1, the input component of the system is hierarchically divided into several subcategories or levels. These levels are entitled from smallest to largest--first, second, and third level input aggregates. Starting with the largest, the third level aggregate contains all inputs into the system. At the second level, system inputs are divided into educational and non-educational inputs. The educational inputs are those supplied by the educational system. They are divided at the first level of aggregation into quantity-related and quality-related inputs. Quantity inputs refer to those inputs associated with the amount or intensity of education during a given cycle (e.g. contact hours per curricular area, number of curricular areas completed). Quality inputs refer to those inputs associated with the excellence of educational inputs during a given cycle (e.g. curricular content, method of presenting content). A cycle is defined as one complete pass through the system.

Non-educational inputs are all inputs which are not provided by the educational system. At the first level of aggregation in the input hierarchy, they are divided into participant-related and non-educational, environment-related inputs. The participant inputs refer to those inputs which the participant brings with him when entering and which he retains during the educational system cycle (e.g. ability, family background, past education). The non-educational environment inputs are made up of those environmental inputs not provided by the educational system (e.g. labor market conditions, community resources). Non-educational, environment inputs are differentiated from participant inputs in that environmental inputs are not in the possession of the participant.

Following through the educational system, all inputs move into the process component; it is here that the inputs interact and combine before forming the output component of the system. This model accounts for the process component only in terms of its inputs. The output component which results is a combination of only those inputs related to the educational system's process.

The generalizable education system shown in Figure 1 can be represented symbolically as follows:

Third level of input aggregation--

$$Y = f(X)$$

where:

Y = system output

X = system input

Second level of input aggregation

$$Y = f(X_1, X_2)$$

where:

Y = system output

X_1 = educational input

X_2 = non-educational input

First level of input aggregation --

$$Y = f(X_{11}, X_{12}, X_{21}, X_{22})$$

where:

Y = system output

X_{11} = educational quantity-related input

X_{12} = educational quality-related input

X_{21} = participant-related input

X_{22} = non-educational environment-related input

Specific system inputs (no aggregation) --

$$Y = f(X_{11}^1, \ldots, X_{11}^i, X_{12}^1, \ldots, X_{12}^j, X_{21}^1, \ldots, X_{21}^k, X_{22}^1, \ldots, X_{22}^m)$$

where:

Y = system output

$X_{11}^1, \ldots, X_{11}^i$ = educational quantity-related inputs, their number being equal to (i)

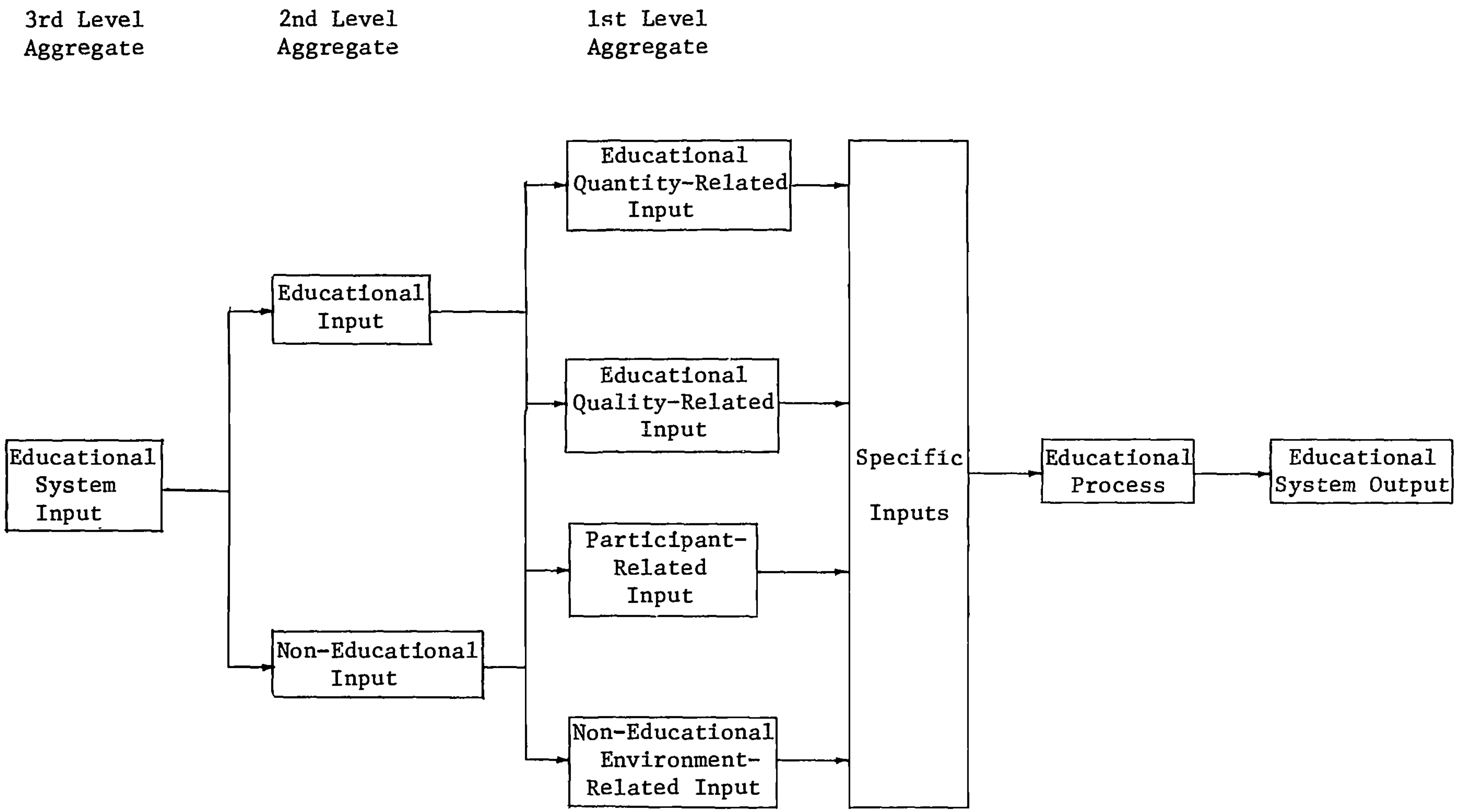
$X_{12}^1, \ldots, X_{12}^j$ = educational quality-related inputs, their number being equal to (j)

$X_{21}^1, \ldots, X_{21}^k$ = participant-related inputs, their number being equal to (k)

$X_{22}^1, \ldots, X_{22}^m$ = non educational environment-related inputs, their number being equal to (m)

Conceptually, the input identification model is intended to fit the generalizable educational system and in so doing perform two functions. First, it categorizes and hierachically organizes the specific inputs and, thereby, permits system analysis at various levels of input aggregation and of various categories of inputs. Second, the model provides a framework for separating the relevant and non-relevant inputs.

Figure 1: Generalizable Education System



These functions serve to identify and direct management's decisions to a particular first or second level input aggregate for more macro level decisions and to specific inputs within a first level aggregate for micro level decisions. At higher levels in the administrative organization of an educational system, direction to a higher level input aggregate may be adequate. However, from an operational perspective it is only the specific inputs that can be manipulated.

A Proposed Statistical Model

The statistical model which is to represent the conceptual input identification model serves the function of separating relevant and non-relevant inputs. The potential of the model is constrained by the feasibility of existing statistical methods and available data.

Multiple linear regression is proposed as one means of modeling the generalizable educational system and, in so doing, of identifying its relevant inputs. Although multiple linear regression as a modeling device has several limitations which are discussed later in this report, its choice is based on its simplicity and adaptability.

Using regression notation, the symbolic model is as follows:

$$Y = B_o + B^1_{11} X^1_{11} + \ldots + B^i_{11} X^j_{11} + B^1_{12} X^1_{12} + \ldots +$$

$$B^j_{12} X^j_{12} + B^1_{21} X^1_{21} + \ldots + B^k_{21} X^k_{21} + B^1_{22} X^1_{22} +$$

$$\ldots + B^m_{22} X^m_{12} + E$$

B_o = regression constant

$B^1_{11} \ldots B^m_{22}$ = partial regression coefficients for the inputs they precede

E = unmeasured inputs plus error

In verbal terms, the statistical model states that educational system output is a linear function of educational quantity-related, educational quality-related, participant-related, and non-educational environment-related inputs.

At this point, the number of inputs is limited only by the number that can reasonably be measured. Ideally, the statistical model would then be used to separate relevant and non-relevant inputs. Stepwise multiple linear regression could be used to identify inputs which remain in the model's equation at some selected level of meaningfulness. Specific inputs could later be re-grouped into input aggregates for separate analysis and interpretation. Using the criterion of proportion of variance in system output accounted for, the relevance of input aggregates or specific input variables within an input aggregate could be assessed using this model.

However, under realistic conditions, the number of potentially relevant inputs will usually far outnumber the educational systems of the same type being assessed. This condition renders the regression methods infeasible if the ideal implementation procedure is followed.

An alternative procedure, expecially for initial implementation of the model, is to operate in reverse order. Using regression analysis, each category of inputs at each level of input aggregation is analyzed separately. Analysis begins at the first level of input aggregation. Four separate analyses are conducted at this level: (a) all measured educational quality-related inputs, (b) all measured educational quantity-related inputs, (c) all measured participant-related inputs, (d) all measured non-educational environment-related inputs. The dependent variable in each of these analyses is the system output measure. Stepwise multiple linear regression may be used to select the important inputs, in each of the four categories. If stepwise regression is used, the criterion determining importance is the ability of an input variable to statistically account for variation in output between systems.

Those inputs, selected as important at the first level of input aggregation, are combined to form the input included in analysis at the second level of aggregation. Two analyses are conducted at this level: (a) selected educational input, and (b) selected non-educational inputs. Again, stepwise regression may be used to select important inputs. The selected inputs are then grouped for the final analysis. The final analysis identifies those inputs to be included in the production function for the educational system being analyzed.

In using this procedure, elimination of specific inputs should be delayed until it is necessary to preserve the validity of the regression equation in terms of degrees of freedom (e.g. number of predictors versus sample size). Delaying elimination as long as possible maximizes the opportunity for a particular input to show its effect on output, especially through interaction with inputs in other categories. Although this alternative procedure is not conceptually ideal, it provides a practical means of implementing the input identification model.

Whatever procedure is used in implementing the model, the final decision about adequacy in input identification is determined by the proportion of variance in system output which is accounted for by the selected inputs. If input identification is judged to be adequate using this criteria, then the inputs retained are identified as a step toward production function formulation for the given education system. If input identification is judged inadequate, then new, potentially relevant inputs must be selected for analysis. In this way, input identification is an iterative process involving more and more complete identification.

Assumptions and Limitations of the Proposed Statistical Model

The assumptions made in using the multiple linear regression model are that the relationships between inputs and system output are linear, and that the fixed X-model can be used to analyze this relationship. The fixed X-model assumes:

1. Y is normally distributed for the hypothetical population of each combination of X's.

2. The variance of Y for the hypothetical population of each combination of X's is equal.

3. Y is independent between hypothetical populations of each combination of X's.

The limitations of this regression model are inherent in the data available and the statistical methods used. The major limitations are as follows:

1. A sizable number of educational systems of the same type must be used if the statistical analysis is to be feasible. This is the limitation which most seriously restricts ideal implementation of the input identification model. Alternative procedures to the ideal implementation, as previously explained, may serve as a practical means of circumventing this limitation in initial model try-outs.

2. Prediction in terms of accounting for variance in output must be very high if the findings are to have reliable implications. When large amounts of variance are unaccounted for, relationships between inputs and outputs and between inputs themselves which are suggested by the regression model may be very misleading. The inclusion of new inputs may drastically change previously existing statistical relationships. This limitation is especially relevant for inputs which account for relatively small amounts of output variance.

3. The regression model determines the importance of various system inputs by the relationships between systems in the amount of specific inputs used and output produced. Two limitations result from this method of identifying important inputs. First, certain inputs necessary to the functioning of the educational system, but not related to differences in system output, may not be selected as important by regression analysis. However, a production function for an educational system should contain all necessary inputs to that system. Second, systems equal to output, but varying in inputs, are not feasibly analyzed using the regression model. Existence of variation in system output is prerequisite to using it as a criterion in selecting important inputs by regression.

IMPLEMENTATION OF INPUT IDENTIFICATION MODEL

The objective of implementing the input identification model is to select the inputs for a given educational system which should be included in the production function for that system. Toward this end there are three necessary characteristics of the educational system upon which the model is to operate. There must be: (a) a measured feasible output, (b) an initial measured set of potentially relevant inputs, and (c) enough educational systems of the same type to make the analysis valid.

Given these prerequisite characteristics, several questions can be asked of the model. Some examples are:

1. What is the significance of each of the first and second level input aggregates in terms of the output measure before and after controlling for the relationship of other aggregates?

2. Which are the most important inputs in each of the first and second level input aggregates before and after controlling for the relationship of other aggregates?

3. Which inputs should be selected for inclusion in the production function of the educational system?

4. What is the adequacy of inputs selected in accounting for variation in system output?

Answers to these and other potential questions which can be asked of the input identification model should bring the selected educational system closer to valid production function application. The immediate value of these answers is the identification and organization of information necessary for such application.

SUMMARY

Identification of important educational system inputs is a major problem to be solved before production function theory can be applied in education. This report presents one method aimed at solving this problem.

The method is defined in the form of an input identification model. It is conceptually a model of a generalizable educational system. This model serves two functions: (a) it hierarchically and categorically organizes the specific inputs and, thereby, permits system analysis at various levels of inputs and (b) it provides a framework for separating the relevant and non-relevant inputs.

Multiple linear regression is proposed as one means of operationalizing the conceptual model; it is not, however, the only means. Linear regression was chosen because of its simplicity and adaptability. As was pointed out, the use of regression analysis to select important input requires certain assumptions and encompasses several limitations.

Ideal implementation of this model necessitates the existence of precise measures of all possible inputs and outputs of an educational system. The review of literature revealed that this is not a realistic requirement for a feasible model at this time. However, the model which is presented can be used as an iterative step in complete input identification. Measures of all possible inputs or the ideal measure of output are not necessary to initialize the model and model implementation can indicate that other inputs must be measured or a new output measure selected.

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