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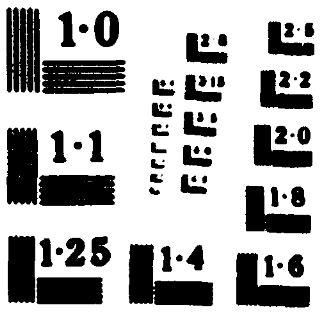
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A NEW APPROACH TO THE MEASUREMENT OF EDUCATIONAL OUTCOMES

FOR INSTITUTIONS OF HIGHER LEARNING

by

Bruce Parley Christensen

A dissertation submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Economics

The University of Utah

December 1984

THE UNIVERSITY OF UTAH GRADUATE SCHOOL

FINAL READING APPROVAL

To the Graduate Council of The University of Utah:

I have read the dissertation of Bruce Parley Christensen in its final form and have found that (1) its format, citations, and bibliographic style are consistent and acceptable; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the Supervisory Committee and is ready for submission to the Graduate School.

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THE UNIVERSITY OF UTAH GRADUATE SCHOOL

SUPERVISORY COMMITTEE APPROVAL

of a dissertation submitted by

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This dissertation has been read by each member of the following supervisory committee and by majority vote has been found to be satisfactory.

August 13, 1984	Chairman James P. Gander
August 13, 1984	David Kiefer
August 13, 1984	Iver E. Bradley
August 13, 1984	Stephen E. Reynolds
August 13, 1984	Stephen F. Seninger

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ABSTRACT

There currently exists an extensive literature on the economics of education. Part of that literature addresses and the use of educational production functions for the measurement of educational output. Most of that literature has been directed at elementary and secondary education with only a small part directed at the university level. The dominant critique of all these works but particularly those accomplished for institutions of higher learning deals with the measurement of outputs. Most critics agree that educational output is multi-product and yet nearly all developed models treat the output as a single product function. This dissertation thoroughly examines existing literature, It develops appropriate joint product theory, and applies the theory to the measurement of output at universities. The outputs selected for measurement are finishers and dropouts, although the value of dropouts to society is not precisely known. These outputs have the effect of creating a study on attrition and its determinants for universities. The methodology selected to develop the models which in turn test the hypothesis that joint products of finishers and dropouts is a valid, worthwhile output measurement is that of linear subjective econometrics. One interesting facet of subjective econometrics is the development of prior opinions through elicitation. This was accomplished using opinions of 'experts;' those who have experience with admission processes and implicitly the attrition of students. The institution selected for study is the Air Force Academy. Three general classes of inputs were

described with scale of admissions having a significant role in the rate of attrition. Entering class characteristics were also of statistical importance in that admissions policies which admit classes with increased academic achievement levels while at the same time have the class be a more homogeneous unit are policies which theoretically will increase attrition. The third group of inputs, institutional characteristics, exhibited mixed results. The major contributions of this dissertation are: (1) the appropriate use of joint products in measuring educational outcomes, (2) the methodology of Bayesian econometrics in educational production, and (3) the integration of educational production function literature with that of attrition; i.e., the use of dropouts as an explicit output of universities.

ACKNOWLEDGMENTS

Every dissertation is the product of numerous hours of work by the author and many other individuals. A special thanks is given to the outstanding, professional members of my committee, Dr. James Gander (chairman), Dr. Iver (Ed) Bradley, Dr. David Kiefer, Dr. Stephen Reynolds, and Dr. Stephen Seninger. All of these members remained extremely busy, engaged in their respective fields, yet they found time to provide valuable assistance, making this possible.

A special debt of gratitude is extended to Colonel Michael O'Connell, past Director of Research at the United States Air Force Academy (USAFA) and his successor, Lieutenant Colonel John Swiney. They and their staff were extremely helpful in providing data and valuable input to this study. The staff in the USAFA, Office of Research was most congenial and cooperative. The same debt of gratitude is owed to Ms. Joyce Thorsen and her staff at the University of Utah for their timely cooperation and assistance with the two-year MBA data. In addition, helpful comments about the educational aspects of this effort were provided by Dr. Steven Bossert, Director of Educational Administration Studies at the University of Utah

Last but certainly not least, deep appreciation is expressed to a most supportive wife, Lorna, and to five patient children who survived the many hours of missing a husband and father and somehow managed to maintain composure during the pressured times.

CHAPTER I

UNIVERSITY ATTRITION--BACKGROUND

Introduction

Today, higher education is faced with a situation where only 40-50 percent of an entering freshman class at the university will graduate from that university. In addition, the average length of time to reach graduation has extended well beyond the previous standard of four years; between 30 and 40 percent of entering students never complete their desired degree goal.[1] When transposing this attrition into costs and the value to society of the unfinished product, a sizeable resource allocation problem exists at the university or college level of academia.

In the United States, as of 1966, over 6 percent of the annual gross national product (GNP) was being spent on formal education.[2] Andersen (1981, p. 42) indicates that well over 2 percent of the GNP was being spent on higher education in 1966. By 1975, over 86 billion dollars of national resources (nearly 6 percent of GNP) were being expended at the college or university equivalent level.[3] That equated to $10,151 annually per student. The latest data published by Andersen (1981) for 1979 show the trend slowing but then projects further increases in both percent of GNP and cost per college student for the early 1980s. If calculated on a cost per graduate basis, the annual university costs reach even higher levels.[4] Because these costs (per student or per graduate) are so high, the study of the economics of education is essential to efficient allocation of national resources. In particular the concern here is for those costs which apply to attrition. The value to society of the unfinished product is left for later research.

This dissertation effort examines attrition cost at a university in the context of a production function. A production function for a firm shows the relationship between inputs (those of the firm as well as raw materials) and outputs. An educational production function shows the relationship between institutional and student inputs and a measure of institutional output.[5] "In setting school policy and in long-range educational planning, knowledge of the educational production function is essential to efficient resource allocation" (Bowles, 1970, p. 12). The concept of a multi-product output for institutions of higher education as the output relates to graduates and nongraduates is tested. Once a student is admitted to a university and begins attending, that student can either graduate (G) or not graduate (N). Because the factors used in producing G are also used in producing N, the two products are technically related and the production law must be considered simultaneously for all products - a joint product production process (Frisch, 1965, p. 269).

This dissertation treats the instruction portion of a university's output as a joint product process in the development of an educational production function for institutions of higher learning. Such a production function highlights information pertaining to attrition at universities.

Overview

The remainder of Chapter I outlines one specific university which has expressed concern with the attrition problem. A second data set is also briefly described. The second study is included, not necessarily as a basis for comparison, (it is nearly impossible to examine two 'similar' entities without making a comparison), but to give a broader base for the testing of theories set forth herein. The Chapter also explores a brief history of the economics of education and presents a summary of the methodology used in this study. Chapter II is a review of the literature as it pertains to the educational production function approach to the economics of education. It includes a review of the literature pertaining to attrition at universities. Chapter III contains a detailed explanation of the theory, models, and hypotheses proposed. The data descriptions and analyses are found in Chapter IV, with the conclusions, summary, and recommendations of this dissertation in Chapter V.

Specific Problem

One university which has shown concern for the problem of attrition is the United States Air Force Academy (USAFA).[6] The USAFA differs somewhat from the typical university in that its specific purpose is to educate and prepare career officers for the United States Air Force.

> This mission is accomplished through a four-year program of academic studies, leadership and military training, physical education and athletics. Completion of the curriculum entitles the cadet to graduate with a Regular Air Force commission and a Bachelor of Science degree in one of 23 different academic majors.[7]

Because of this unique mission, the USAFA can be likened to a small private university which differs from the larger state operated universities in attrition rates and dropping-out of students.[8] Even though attrition rates are generally lower at small private institutions, attrition can still be a problem in resource allocation as previously indicated. In his book Human Capital, Gary Becker (1964, p. 93) indicates that he found the internal rate of return, the return to the dropout, to be some four points below the rate of return for college graduates and far enough below ten (10) percent (rate of return) to suggest that some college, i.e., the unfinished product, is a relatively unprofitable investment.[9] Therefore, attrition becomes even more of a problem at the USAFA when one considers the uncertain value to society of the unfinished product and the fact that taxpayers support that institute.

The source of funding for the USAFA causes concern for attrition at all levels of USAFA management. An informally stated goal of the Academy is to graduate 1,000 cadets each year with 70% of those graduates being medically and physically qualified to enter USAF pilot training program.[11] Initially one might conclude that this poses no special problems. By simply admitting more students, (increasing scale of operations) or lowering graduation requirements, these goals could be satisfied. However, the USAFA operates under two additional constraints which make the attrition problem loom large. The first is the limited facility constraints at the Academy. Cadet dormitories contain 2,160 cadet rooms.[12] The second is a limitation imposed by law. In 1964, Congress authorized a cadet wing strength of 4,417 students as of 1 October of each year.[13] Assuming a uniform attrition rate for each class over all four years of cadets' academy experience, Table 1 reflects the hypothetically possible attrition numbers and percentages

Table 1--Hypothetical, Uniform Attrition of USAFA Cadets While Meeting Constraints

	Year of School				
	1	2	3	4	TOTAL
Beginning No. Students	1167	1125	1083	1041	4,416
Attrition Number	42	42	42	41	167
Attrition Rate	3.6%	3.7%	3.9%	3.9%	
Ending No. Students	1125	1083	1041	1000	
Attrition Rate Per Class	(167 ÷ 1167) 14.3%				

while still meeting the goal of 1,000 graduates.

Table 2 contrasts Table 1 in the time in which students drop from school and assumes all attrition occurs during or at the end of the first year. It is obvious that under such circumstances, the maximum attrition rate could be higher while still meeting the goal of 1,000 graduates. A third alternative is to have all dropouts occur during or at the end of the senior year. Such a case would provide the minimum possible attrition rates. Table 3 depicts that hypothetical possibility. It is rather intuitive that the third alternative is not desirable for reducing costs per graduate because of high costs involved in carrying students for four years and then losing them. It is as equally obvious that the ideal circumstances depicted in Table 2 do not and cannot exist in a college environment. Hence, the attrition problem facing the USAFA and any other university which is concerned with keeping a larger proportion of beginning freshmen through to graduation.

Table 2--Hypothetical, All Attrition During First Year for USAFA Cadets While Meeting Constraints

	Year of School				
	1	2	3	4	TOTAL
Beginning No. Students:	1417	1000	1000	1000	4,417
Attrition Number:	417	0	0	0	417
Attrition Rate:	29.4%	-	-	-	
Ending No. Students:	1000	1000	1000	1000	
Attrition Rate Per Class:	(417 ÷ 1417) 29.4%				

Table 3--Hypothetical, All Attrition During Fourth Year for USAFA Cadets While Meeting Constraints

	Year of School				
	1	2	3	4	TOTAL
Beginning No. Students:	1104	1104	1104	1104	4,416
Attrition Number:	0	0	0	104	104
Attrition Rate:	-	-	-	9.4%	
Ending No. Students:	1104	1104	1104	1000	
Attrition Rate Per Class:	(104 ÷ 1104) 9.4%				

Second Data Set

The second source of data examined comes from the University of Utah, two-year Master of Business Administration (UofU,MBA) program. It is well to re-emphasize that this second study is not accomplished for the primary purpose of comparison with the first study but rather to provide additional descriptive information regarding attrition from higher education.

Background on the Economics of Education

The economics of education as a subject of interest was virtually non-existent until approximately the mid 1940s.[14] Since then the interest has grown at an almost exponential rate, until today there are well over 2000 pieces of literature on the subject.[15] These data are only used to show the interest in this topic. This author predicts that as education costs continue to climb the resource expenditure ladder more and more will be added to the expanding list of references.

Even though this list of literature is relatively long and still growing, the approaches used to study the topic vary considerably. One such approach, a theory on the economics of education, is the "Human Capital Theory." The basic premise of Human Capital Theory is that variations in labor income are due, in part at least, to differences in labor quality in terms of the amount of human capital acquired by the workers.[16] There have been some variations and many critiques published about Human Capital and the variations espoused by various authors, (Cohn, 1979, pp. 27-59) but the basic idea as originally put forth can be depicted by Figure 1.

A second approach, a methodology which is widely used in all areas

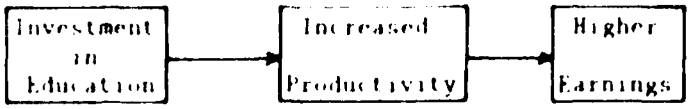

Figure 1. Human Capital Theory

of economics, is "Cost-Benefit Analysis." This method of studying education employs the study of all costs and benefits associated with education. Then various criteria are applied and the most favorable alternative of those under study is selected. Of the three criteria most frequently used in Cost-Benefit Analysis, Net Present Value Rule (NPV), Internal Rate of Return Rule (IROR), and Benefit-Cost Ratio Rule (B/CR),[1] IROR is used in the majority of studies. As with the Human Capital Theory, there have been numerous studies on the economics of education using cost-benefit analysis techniques. The pioneering efforts for Cost-Benefit Analysis of education belong to Houthhakker (1959), H.P. Miller (1960), G.S. Becker (1960, 1964) and Hansen (1963) (Cohn, 1979, p. 113).

A third method for studying the economics of education is the educational or manpower planning approach. This approach promotes productivity in a society by matching expected demand for skills with the supply of those skills. The main purpose of this method is to forecast manpower needs by skill categories and then transform those requirements into educational requirements (Cohn, 1979, p. 316). Here too, there are several different forms of educational planning. Parnes (1962), Eckaus (1964), and Bacchus (1968) have all used the "Manpower Requirements" approach. One called "Social Demand" was used and endorsed by the Robbins Committee on Higher Education (1963). This approach was never formally endorsed in the United States. The "Rate of Return" approach uses the net present value of future income streams for various educational programs. Those programs having a positive net present value are stimulated by educational planning authorities. Blaug (1967) prefers a synthesis of all three planning approaches, Manpower Requirements, Social Demand, and Rate of Return.

Another area dealing with the study of the economics of education is the relationship between economic growth and education. The first serious attempt to quantify the contribution of education to economic growth was done by Schultz (1961) where he concluded that 36 to 70 percent of the increase in labor income (between 1929 and 1957) was attributable to the increase in educational stock (Cohn, 1979, p. 149). Perhaps the most complete analysis of the educational contribution to economic growth was accomplished by Denison (1962, 1964, 1967, 1974). He concludes that education contributed approximately 20.6 percent to the rate of per capita national income growth between 1929 and 1969 (Cohn, 1979, p. 155). Others who have researched this portion of the economics of education include Selowsky (1969), Correa (1970), Razin (1977), Psacharopoulos (1973), Delaplaine and Hollander (1970), Firestone (1968), Griliches (1970), and Machlup (1970, 1975).

Another major method for studying the economics of education is through the use of the educational production function. The preponderance of the discussion on educational production functions is reserved for Chapter II. Only an amount sufficient to explain the methodology of this paper is presented here.

Methodology

Most of the work which has been done regarding educational production functions has been directed at either elementary or secondary education processes (Cohn, 1979, pp. 174-87). Very few works have appeared on higher education. One of the major critiques of traditional educational production functions is the *measurement* of output. Because educational institutions are multi-product in nature, output measures which attempt to define the total output with one output *measurement* fall short of reality.[18] Such production functions do not accurately portray the output of the educational process.

In the university educational process, the traditional mission is threefold: (1) to provide instruction, (2) to do research, and (3) to provide community service (Casmoski and Loepfer, 1979). Even within each of these missions there exists a multiplicity of outputs for a university. This study examines only a portion of the instruction mission of a university using the multiple product output approach. The two measures of output are graduates and nongraduates. Figure 2 depicts the univerisity production process as envisioned herein.

An analogy that can be used to illustrate the desired meaning of Figure 2 is that of a chairmaker. For simplicity, assume the only raw material input to be wood. The output will be a combination of finished chairs and unfinished (or defective) chairs. The wood is used to produce both products jointly; from a given quantity of wood, both products result. These products are technically connected or this is a multi-ware production process. Under such circumstances, the production process must be considered simultaneously as a set of production functions. However, if the products are linked together or perfectly

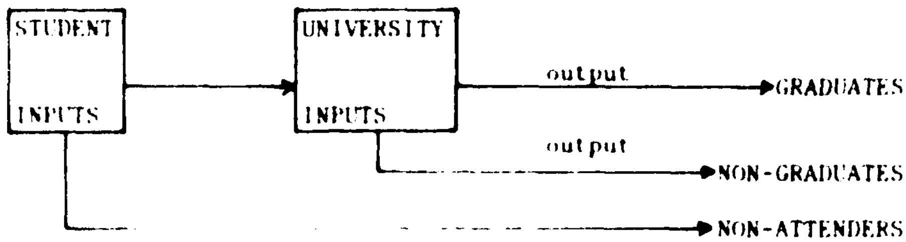

Figure 2. University Production Process

coupled in such a way that the quantity of one product is a given function of another product, then the total output of both products is determined implicitly by the quantities of the factors, and the simultaneous system of production functions is not required (Frisch, 1965, pp. 220-1). Such is the case throughout this study. Just as the chairmaker knows that, given a certain quantity of wood, if X number of finished chairs are produced then Y of unfinished chairs will also result, so a university takes in a certain number of students, if N do not graduate then G will. For a different number of students a different mix of N and G may occur. Therefore, the multiple output as indexed, say by some function of the ratio of N:G, is a function of the number of students admitted (scale) and several other factors, including quality of input and some process inputs, which are defined as individual variables later in the model definition (see Chapter III).

The approach used herein is macro in the sense that the study does not center upon the characteristics of individual students or the micro decision process a university may employ, but rather upon class characteristics. The university problem is similar to that of a large automobile producer where the Environmental Protection Agency directs that the fleet of automobiles produced must meet certain minimum standards.

Any one car produced may fall way short of the desired standard but the fleet overall must meet that standard. Similarly, any one student may not meet the desired entrance standards but the university goal is for the group, not the individual. This is especially important in that there currently exists no easy method for a university to determine or accurately predict from preadmission testing, which individual student will drop out of college (Cope and Hannah, 1975, pp. 104-5; also Beal and Noel, 1980, p. 3). Thus there is no assurance that any particular student will persist to graduation. It is precisely the entering class characteristics which must be evaluated in determining the proper mix of students to best meet the attrition goals of an institution.

The Air Force Academy, by virtue of its goal to have 1,000 graduates per class and the law restricting the number of students on 30 September of each year, indicates a willingness to accept attrition of from 9-36 percent (see Tables 1, 2, and 3). Therefore, the characteristics of the entering freshman class must be such that the accepted retention withdrawal rates can be met. The emphasis is not on each particular student at entrance. It is upon the entering class in total. That is where the emphasis of this study is placed - the mix of students which best gives the characteristics so that desired retention goals can be achieved.

The relationship between the inputs and outputs is defined through the use of linear subjective econometrics. In short, subjective econometrics emphasizes the distribution of the coefficient values, not just the coefficient values themselves as in classical statistics. And, the posterior distribution of coefficient values is a weighted linear convex combination of the maximum likelihood estimator and the prior mean with weights proportional to the precisions of each. Therefore, maximum likelihood estimators are developed from the data. Prior opinions are elicited from 'experts',[19] those personnel actively involved in the admissions process at the USAFA. The models are specified using the linear convex combinations of appropriate pieces of data.

It is an accepted fact that attrition rates vary for each year in college,[20] so separate models are developed to reflect the output for each level of education achieved by the students. Therefore, there are four separate models of production for the USAFA representing freshman, sophomore, junior and senior levels of education. In addition, there is an aggregate model to reflect the output of the university for a given year, i.e., the total output in terms of G and N for each level of a class's education. (In this context, G refers to successful completion of the school year.) The UofI,MBA data is presented in terms of one aggregate model.

Assumptions and Limitations

The exact form which an educational production function should take is not known with certainty.

> The dearth of knowledge concerning the learning process makes any a priori specification of form for the estimation of educational production relationships particularly difficult. The notion of diminishing marginal product is appealing, although not well established in the field of education. A function linear in the logarithms of the variables would seem somewhat superior, particularly in view of the possibility of positive interactions between inputs. Nevertheless, the restrictions of the Cobb-Douglas function are severe.
> [Bowles, 1970, p. 19]

Bowles (1970, p. 16) indicates that he prefers the simple linear additive form. That is the form which the models take in this effort.

Another limitation imposed by the structure of the model is the number of variables included in the various models.[21]

> In choosing the appropriate dimensions of input for examination, the analyst is engaged in a delicate balancing act. If particular variables are omitted, the estimated effects of those included may be biased. For example, teacher-to-pupil ratio and teacher quality are positively related and both of these inputs are related to student performance. Including either of these measures in multiple regression analysis, without including the other, results in overestimating the effect of the included variable. On the other hand, including too many separate dimensions may make it impossible to obtain reliable estimates of the effect of any of these variables.
>
> [Bowles, 1970, p. 24]

Closely related to that problem is the number of degrees of freedom. The individual models' data base for the USAFA includes at most only 27 sets of data points. The degrees of freedom quickly diminish as more and more variables are included in the model. Therefore, the variables which are included were limited but carefully selected to test such determinants of output as scale, input quality, and process technology.

Another limitation is in the conclusions drawn from this study. Because it is macro in nature and examines the characteristics of a group along with group defined institutional output, inferences cannot be drawn about the corresponding individual-level characteristics. The conclusions must of necessity be limited to group conclusions.[22] However, this approach does provide policy value to the institutional decision maker in that the analysis attempts to get at the determinants of the output mix of N and G.

Summary

This chapter has outlined the need for continuing emphasis on the economics of education and an extremely brief review of various methods for studying the subject. The particular methods employed in this study were outlined with details of the models, theories, and hypotheses to follow in Chapter III. With the limitations and assumptions of educational production functions and the data for this study as already briefly described, a review of the literature as it pertains to attrition and educational production functions is imperative and follows in Chapter II.

Notes to Chapter I

1. Robert Cope and William Hannah, Revolving College Doors, New York: John Wiley & Sons, Inc., 1975, 1-5, 101. See also: Marilyn Abildskov, "For Some Students, College is Their Profession," The Daily Utah Chronicle, 93, 6 Feb 1984, 1; Philip E. Beal and Lee Noel, What Works in Student Retention, Report of a joint project of The American College Testing Program and The National Center for Higher Education Management Systems, 1980, 1; A. June Gleeson, An Analysis of the Costs of Part-Time and Full-Time Study at Colleges of Advanced Education, unpublished Ph.D. dissertation, LaTrobe University, Sep 1979, 154, 168-71; Frank B. Jex, A Study in Persistence: Withdrawal and Graduation Rates at the University of Utah, Counseling Center Research Report 12, Salt Lake City: University of Utah, 1961, 2-8; and Cash Kowalski, The Impact of College on Persisting and Nonpersisting Students, New York: Philosophical Library Inc., 1977, 3.

2. Samuel Bowles, "Towards an Educational Production Function," in Education, Income, and Human Capital, W. Lee Hansen, ed., New York: National Bureau of Economic Research, 1970, 11. See also: Charles S. Benson, The Economics of Public Education, New York: Houghton Mifflin Co., 1968. Ref in Louis J. Rodriguez and Dewey D. Davis, The Economics of Education, Lincoln: Professional Educators Publications, Inc., 1974, 72-3.

3. Elchanan Cohn, The Economics of Education, Cambridge: Ballinger Publishing Company, 1979, 11. Hereafter, the term university will inlcude all postsecondary education unless specified otherwise. Also see Charles J. Andersen, ed., 1981-82 Fact Book for Academic Administrators, Washington, D.C.: American Council on Education, 1981, 40.

4. John Vaizey, "The Costs of Wastage," Universities Quarterly, 25, Spring 1971, 141. See also: Lawrence S. Kubie, "The Ontogeny of the Dropout Problem," in Lawrence A. Pervin, et al. eds., The College Dropout and the Utilization of Talent, Princeton: Princeton University Press, 1966, 26; C. Selby Smith, The Costs of Postsecondary Education, South Melbourne: McMillan, 1975, in Gleeson (1979), 153; and P.A. Watt, "Economies of Scale in Schools: Some Evidence from The Private Sector," Applied Economics, 12, 1980, 237.

5. J.A. Kershaw, "Productivity in American Schools and Colleges," in Mark Blaug, ed., Economics of Education, II, Baltimore: Penguin Books Inc., 1969, 310. See also: Bowles (1970), 12.

6. Topic submitted by USAFA/RRE (Office of Research) in The United States Air Force Compendium of Research Topics, Vol. I, Maxwell AFB, AL: Air University, 1982, 231.

7. The United States Air Force Academy--Questions and Answers, a brochure prepared for visitors to the USAFA to answer their questions, Washington, D.C.: U.S. Government Printing Office, 679-075/246 - 1983, 1.

8. Robert E. Iffert, "Retention and Withdrawal of College Students," U.S. Department of Health, Education, and Welfare Bulletin 91, Washington D.C.: U.S. Government Printing Office, 1958, 4, 17-8. See also: Cope and Hannah (1975), 101-2.

9. Gary S. Becker, Human Capital - A Theoretical and Empirical Analysis, with Special Reference to Education, New York: National Bureau of Economic Research, 1964, 93. See also: Richard Perlman, The Economics of Education: Conceptual Problems and Policy Issues, New York: McGraw-Hill Book Co., 1973, 77.

11. These goals were informally established in a personal letter from Lieutenant General Andrew P. Iosue, USAF Deputy Chief of Staff for Manpower and Personnel, to Major General Robert Kelley, Superintendent of the USAFA, in July 1982. The goal was two-fold, to graduate at least 1000 fully qualified officers and have a minimum of 70% qualified for pilot training.

12. See note 7, p. 6. Figured at two cadets per room, there are sufficient rooms for 4,278 cadets. However, not all rooms are available for cadet living. Some rooms are used for storage of cadet belongings and other high value storage.

13. The law went into effect in 1964 under then President Lyndon B. Johnson, increasing cadet strength to 4,417 as of 1 Oct and 4,546 as of 1 Jul. The difference in number is to accomodate those who drop out after or during Basic Cadet Training (BCT) held during the summer prior to the freshman year of school. See Congressional Bill HR7356. Also see note 7, p. 12. Above strengths also confirmed in letter to author from USAFA/RRE, Colonel Michael J. O'Connell, USAF, on 30 Nov 1982.

14. Mark Blaug, Economics of Education, A Selected Annotated Bibliography, 3rd ed., Oxford: Permagon Press, 1978, preface. Even though the subject is relatively new, it is one which was understood by Adam Smith in 1776 as well as Alfred Marshall in the 1890s. See: Adam Smith, The Wealth of Nations, Chicago: Encyclopedia Britannica, 340-3; and Alfred Marshall, Principles of Economics, 9th ed., C.W. Guillebaud, ed., 2 Vols., McMillan Co., 1961, 211-6.

15. Professor Mark Blaug published a book entitled, Economics of Education, A Selected Annotated Bibliography, in three separate editions. The first edition, published in 1966, contained 800 listings. The second edition of 1970 listed 1350 references. And the third edition, 1978, showed 1940 different items, all referencing the "Economics of Education."

16. Cohn (1979), 28. Also see: Gary S. Becker, "Human Capital and the Personal Distribution of Income: An Analytical Approach," W.S. Woytinsky Lecture #1, Ann Arbor: Institute of Public Administration, University of Michigan, 1967; Gary S. Becker, Human Capital, 2nd ed., New York: National Bureau of Economic Research, 1975; Jacob Mincer, "On-the-job Training: Costs, Returns and Some Implications," Journal of Political Economy, (Supplement) 70, October 1962, 50-79; Jacob

Mincer, "The Distribution of Labor Incomes: A Survey With Special Reference to the Human Capital Approach," Journal of Economic Literature, 8, March 1970, 1-26, and Jacob Mincer, Schooling, Experience, and Earnings, New York: Columbia University Press, 1974.

17. A.R. Prest and Ralph Turvey, "Cost-Benefit Analysis: A Survey," Economic Journal, 71, December 1965, 763. See also: Jack Hirshleifer, et al., Water Supply, Chicago: University of Chicago Press, 1960, 152-7, and Cohn (1979), 96-7.

18. The Public Services Laboratory of Georgetown University published a booklet titled A Guide to Education Outcome Measurements and Their Use, in 1975. It is a series of six seminars for use by educators and others interested in the production of education. They feel that "achievement" test scores do not adequately measure the total output of any school, 7-13. In addition, see: Mark Blaug, "The Productivity of Universities," in M. Blaug, ed., Economics of Education, II, Baltimore: Penguin Books, Inc., 1969, 313; Mark Blaug An Introduction to the Economics of Education, London: Allen Lane The Penguin Press, 1970, 269; Bowles (1970), 18; Eric A. Hanushek, "Conceptual and Empirical Issues in the Estimation of Educational Production Functions," The Journal of Human Resources, XIV, Summer 1979, 362; Kershaw (1969), 305; Henry M. Levin, "Concepts of Economic Efficiency and Educational Production," in Education as an Industry, Joseph T. Froomkin, et al., eds., Cambridge: Ballinger Publishing Co., 1976, 152-4; Daniel F. Luecke, and Noel F. McGinn, "Regression Analyses and Education Production Functions: Can They Be Trusted?" Harvard Educational Review, 45, August 1975, 327; and David Segal, Urban Economics, Homewood, IL: Richard D. Irwin, Inc., 1977, 282.

19. See Appendix A for elicitation statements.

20. Raw data for the USAFA supports the statement and reason alone says it must be true; the closer one gets to graduation, the less likely the student is to withdraw. See Gleeson (1979), 170; also Iffert (1958), 100.

21. John Heim and Lewis Perl, The Educational Production Function: Implications for Educational Manpower Policy, Ithaca, New York: Institute of Public Employment, New York State School of Industrial and Labor Relations, Cornell University, 1974, 4.

22. Leigh Burstein, "The Analysis of Multilevel Data in Educational Research and Evaluation," Review of Research in Education, Vol. 8, David C. Berliner, ed., U.S.A.: American Educational Research Association, 1980, 164.

CHAPTER II

A REVIEW OF THE LITERATURE

Introduction

As was evident in Chapter I, the problem addressed in this dissertation is that of attrition from institutions of higher learning and the determinants of attrition. It was also indicated there that the educational production function approach is used but with the added feature of treating output as a joint production of graduates and nongraduates. The body of literature which forms the context for this problem, for the methodology employed, and for the economics of education in general is quite extensive and while it relates to all levels of education the major focus is on primary and secondary education. The methodology of this literature is also very broad in that some studies are extremely anaytical and quantitative in nature while others are very descriptive. Since this dissertation is in the area of applied economic theory, this chapter will review only selected, relevant literature on attrition at universities and the use of production functions in the economics of education. Therefore, the chapter is divided into two major sections (attrition and production functions) with each section being further subdivided into areas of focus to provide readability and also to provide faster reference to specific subtopics in which the reader may be interested. Selected studies on attrition are included in Appendix B while studies using educational production functions are in Appendix C.

The general impressions one gets from the selected literature on attrition can be summarized in the following statements. Although studies have been accomplished at primary, secondary, and higher institutions, the major thrust is directed toward universities. Reasons students give for dropping out of college are generally similar in each of the studies performed and yet the consensus is that there currently exists no adequate method for predicting which entering students will drop before graduation. Finally, 40 to 50 percent of all freshmen entering universities will never complete a degree goal. For the purposes of this dissertation, many of the details of the literature are quite useful to gain an understanding of the problem of university attrition. For this reason, a rather detailed review of the attrition literature is undertaken.

By the same token, the general impressions one gets from the selected literature on educational production functions are: (1) the majority of effort accomplished was done at the primary or secondary level of education, (2) the major problem or critique about these educational production functions deals with the measurement of output, and (3) the primary output measure used was some form of cognitive achievement as measured by test results. The approach used in this dissertation borrows much in general from this extensive literature and then extends it through the joint product approach to output measurement.

Attrition

What it is and Why Study it

Giving a series of statistics about any topic without first defining what is being measured by those statistics would be highly fallacious. The meaning of "dropout" or university "attrition" depends upon the context in which it is measured. One extreme is to define a dropout as one who leaves college for any period of time, regardless of the reason, thus not obtaining the desired degree goal at the same time as the class with which said student originally enrolled. That definition is used by Pervin, Reik, and Dalrymple,[1] as well as Vaizey (1971). Still others imply a definition that only those who drop from school and never complete a degree are counted as dropouts.[2] Such a definition implies that someone requiring a longer period of time to complete the required degree goal, whether inordinately longer or not, is not a dropout but is instead a persister. That is the case in Kowalski (1977) as stated in the title, The Impact of College on Persisting and Nonpersisting Students. One author even goes to the other extreme in differentiating between "successful" students, "readmitted" students, and "dropouts."[3] Not all authors or researchers think that way.[4]

The only way to be completely clear when presenting such statistics is to define precisely what is meant with each statistic offered. Therefore, in the section on attrition statistics which is subsequently presented, precise definitions are proffered to erase any doubt about their meaning and magnitude.

Now it is known that attrition can be defined to suit the particular author, why is it a topic of sufficient importance to study? The main reason is due to the costs of education already mentioned in Chapter I. For those students who are admitted to a university but drop out and never earn degrees, the cost to the individual, the university, and to society is high--both in monetary and nonmonetary terms.[5] The nonmonetary terms are probably as important as the monetary ones. An example from Lawrence S. Kubie illustrates this point.

> When A uses up a place in a medical school or engineering school and then fails or voluntarily drops out, A has lost that discipline not one but two possible scholars or practitioners: i.e., himself and B, who would have been there in A's place if A had not been there; and B might not have become a dropout.
>
> [Kubie, 1966, pp. 26-7]

These social costs cannot be evaluated in monetary terms.

> When a student leaves college before graduating, he evokes a variety of responses from the social milieu, from his college, from his parents, and from himself. These responses may to some degree be appropriate and reasonable, but they are often strongly colored by the kind of emotional excess that an individual's deviation from some widely accepted and institutionalized value system is apt to evoke. . . . In the state of present knowledge, it is of course difficult to demonstrate conclusively to what extent society, whether at the national level or otherwise, is guilty of premature judgements and emotionalism when it looks at the college dropout. There are, however, hints that the guilt is there. The dropout is often referred to as a drain on national resources. He is presumed to represent wasted talent, . . .
>
> [*Pervin, et al.*, 1966, pp. 9-10]

Equally as important in the 'why study' category is the allegation by Cope and Hannah (1975, p. 5) that most university faculty and administrators take a we-would-rather-not-know attitude toward withdrawal data, and thus the extent of the problem. So, if it is a problem (enough evidence has already been cited to at least substantiate that a reduced attrition rate would create a more favorable allocation of resources,) attrition studies can be used to highlight awareness of the problem. Other potential uses of such studies include "the building of models that will allow the prediction of which students will drop out and of the number of students who will drop out."[6] And, of course, to determine from the studies what, if anything, can be done to lower the existing attrition rates.

Statistics

Most authors writing on attrition conclude that the dropout rates vary from college to college and anywhere from 13-50 percent of an entering freshman class will graduate from the university where they started in four years.[7] Kowalski (1977, p. 3) narrows the range considerably by giving the following. Of every 100 students entering the colleges and universities in the United States, approximately forty will complete a bachelor's degree within four years, another twenty will graduate in succeeding years, and approximately forty will not graduate at all. His conclusion is supported by the findings of Laird, Pervin, and Iffert.[8] His findings are also in line with the study by Jex on the Class of 1954. Jex (1961, p. 8) said that 39.5% of the Class, for all public and private institutions in the Unites States, graduated on schedule, i.e., four years after beginning school. When accounting for public institutions only, the completion rate dropped to only 33% for the Class of 1954.

Obviously there are some private institutions which have completion rates significantly higher than 40% to be able to raise the average to that point. Of the universities studied by Kowalski (1977, p. 3), Princeton University had the smallest attrition rate, only 20%, or a successful four-year completion rate of 80%.

Reasons for Attrition

The next logical question to be answered once the attrition statistics have been highlighted, is "why do students drop out of a university?" If attrition rates are to be changed to any degree, it is imperative that a knowledge of reasons for dropping out be known.

Even though there is some commonality, the reasons for student attrition can be as diverse as the students who drop out.

> Dropout studies that are not longitudinal in design typically emphasize the explanations provided by students for dropping out. To accept such post hoc interpretations at face value is a questionable practice, considering the complexity of the dropout phenomenon and the natural tendency for persons to rationalize behavior which might be regarded by others as evidence of failure.[9]
>
> [Astin, 1975, p. 14]

Hence, differences between authors as to causes of attrition do exist. But even then, common reasons emerge. One reason readily agreed upon by most authors and most frequently mentioned is financial problems with a second reason being academic.[10] In two of the previous research efforts, dropout students were permitted to select among several alternatives, those which they felt contributed to their failure to persist to a degree. The results of the Astin (1975) study are shown in Table 4 with those of the Iffert (1958) sample appearing in Table 5.

Astin used twelve reasons for dropping out where Iffert had previously used twenty-one. The top five reasons are presented in Table 6 as a basis for comparison. Financial problems and a general loss of interest are the only two reasons which ranked in the top five of both studies. However, the most interesting similarity between the results of the two research efforts is what occurs when the military reasons are omitted from Iffert. Now financial and boredom are ranked as numbers two and one respectively for both authors.[11] Invocation of the apparently arbitrary decision to overlook the military reasons for quitting school is based on the fact that during the Iffert study, the United States was actively involved in the Korean Conflict and the draft laws were in full effect for young men. In addition, when combined with the women and using the same weighting procedure previously mentioned

Table 4--Astin Study, Reasons for College Dropouts

REASONS[a]	Men % Who Selected	Men Rank	Women % Who Selected	Women Rank	Overall %	Overall Rank
Boredom with courses	36	1	25	3	32	1
Financial difficulties	29	3	27	2	28	2
Other reasons	31	2	24	4	28	2
Marriage, pregnancy, or other family responsibility	11	8	39	1	23	4
Poor grades	28	4	14	7	22	5
Dissatisfaction with requirements or regulations	24	5	20	5	22	5
Change in career goals	19	6	20	5	19	7
Inability to take desired courses or programs	12	7	9	8	11	8
Good job	10	9	6	10	9	9
Illness or accident	7	10	7	9	7	10
Difficulty commuting	3	11	3	11	3	11
Disciplinary troubles	2	12	2	12	2	12

[a]Each dropout was given the opportunity to select a maximum of three reasons from the list of twelve. Hence the total percent being greater than 100%. Information for this table extracted from Astin (1975, p. 14).

Table 5--Iffert Study, Reasons for College Dropouts

Reason[a]	Percent Rating the Reason to be of Some Importance: Men	Women	Rank of Importance[b]: Men	Women
Illness (self)	7.32	10.07	15	7
Illness (family)	8.65	10.07	14	11
Financial (self)	41.38	36.36	2	3
Financial (family)	29.66	32.26	6	4
College too difficult	26.51	19.94	10	8
Needed at home	12.59	12.51	12	10
Marital difficulties	3.62	3.32	18	16
Full-time job	24.15	37.15	7	2
Lonesome and unhappy	14.69	16.55	11	9
Marriage	10.69	49.20	13	1
Too long to commute	6.55	6.55	17	15
Low grades	40.00	22.92	4	6
Military (drafted)	24.62	0	5	21
Military (enlisted)	45.17	.97	1	18
Lost interest	48.00	33.01	3	5
Academic dismissal	18.14	6.90	8	13
Academic probation	21.24	10.09	9	12
Other probation	2.00	.44	20	19

Table 5, cont.

Reason[a]	Percent Rating the Reason to be of Some Importance		Rank of Importance[b]	
	Men	Women	Men	Women
Other dismissal	2.76	1.06	19	17
Disciplinary suspension	1.66	.35	21	20
Housing	6.41	5.31	16	14

[a]Each dropout student was afforded the opportunity to select multiple reasons from the list of twenty-one. Then they were to rank them in order of importance. Information for Table 5 was extracted from Iffert (1958, Table 48, p. 91).

[b]These columns are based upon the "mean rating of the level of importance of the reason for dropout" by men and women respectively.

Table 6--Comparison of Reasons for Quitting School

Reasons	Iffert Men	Iffert Women	Astin Men	Astin Women	Overall
Military (enlisted)	1	18	-	-	-
Marriage	13	1	8	1	4
Financial (self)	2	3	3	2	2
Full-time job	7	2	9	10	[illegible]
Lost interest (boredom)	3	5	1	3	1
Low grades	4	6	4	7	5
Military (drafted)	5	21	-	-	-
Financial (family)	6	4	-	-	-
Other reasons	-	-	2	4	2
School dissatisfaction	-	-	5	5	5

(see note 11), the military reasons fall way out of the top five. Related to that is the increased rate of dropout following the repeal of the draft laws as discovered by Tinto (1975, p. 98). His findings indicate that more students were using higher education as a hedge against being drafted.

Compare the combined results of Iffert and Astin with one of the conclusive statements by Tinto.

> The characteristics of the institution--resources, facilities, structural arrangements, and composition of its members--place limits upon the development and integration of individuals within the institution and that lead to the development of academic and social climates with which the individual must come to grips. These same characteristics are also true with respect to the social system of the college since much dropout appears to result from a lack of congruence between the individual and the social climate of the institution rather than any specific failure on the part of the individual.
>
> [Tinto, 1975, p. 11]

Two other authors conclude their reports by saying that academic, motivation, and finance emerge as the most important determinants of attrition.[12]

Predicting Who Might Drop Out

Given the reasons for dropout, is it possible then to predict with much accuracy who will drop out of college? It has already been asserted and documented in Chapter I that there exists a general inability to predict which students will drop out of college, especially when using preadmission testing.[13] However, there does exist some evidence of certain characteristics which may lead a student to drop out of school. Attributes (sex, race, and ability), precollege experiences (high school G.P.A., academic and social attainments), and family backgrounds (social status attributes, value climates, and expectational climates), all have both direct and indirect impacts upon performance in and subsequent completion of college.[14]

The following conclusions reached by Kowalski (1977, p. 77), while directed to the prediction of individual student success as opposed to the approach taken here, do nevertheless shed light on some of the underlying causes of attrition:

(1) It is unlikely that a student with academic disabilities and personal pressures will continue his education.

(2) Students who have academic and personal problems can be identified as potential dropouts.

(3) The education level of the student's father is highly indicative of whether the student will persist.

(4) A student who maintains a positive personal relationship with his advisor and other faculty members positively influences his chances to remain in school.

(5) Having a definite educational goal in mind enhances persistence possibilities.

Items 4 and 5 coincide closely with the Cope and Hannah (1975, p. 102) statement that the most important factor in a university's holding power over particular students is the student's identification with the college. Students are much more likely to persist in a school which they have chosen because of its clear image values and the program it offers, if the student knows what he or she wants.

> The model of selective admissions based on test scores and grades is inappropriate. Colleges should place more admissions emphasis on "whole-person" indicators of accomplishment (creative writing, a hobby in science, a goal in life, etc.). These students are much more likely to become outstanding individuals than those with high scores on SATs and ACTs, which offer virtually no indication of capacity for

significant intellectual or aesthetic contribution in later years.

[Cope & Hannah, 1975, pp. 104-5]

The answer to the question which began this section (is it possible to identify who will drop out?) is a qualified "no". The qualifications are that certain student characteristics and student background characteristics may lead a student to drop out of a university. As the literature showed, however, one of the most important aspects of a university's holding power over students is the extent of identification that each particular student has with the university. This would seem to imply that "holding power" might override the characteristics and this accounts for the uncertainty of prediction.

Attrition Summary

The statistics from attrition studies indicate that only 40 to 50 percent of a beginning freshman class will graduate in four years from the institution of first matriculation. Of every one hundred students entering a university in the United States, approximately forty will never graduate. A good summary of the reasons for attrition, prediction of quitters, and the studies performed is made by Huber.

> . . . quantitative indices are useful in a rough sense at the lower end of the scale for placement purposes and are quite predictive when one deals with the lowest two deciles in that there is some assurance that these students cannot function at a satisfactory level considering their present level of preparation and ability regardless of other factors of interest, motivation, etc. But for students in the mid and top ranges the degree of correlation between these data and actual performance and retention is insignificant. Another way of expressing it is that in those cases where it is clear that the student can function at a satisfactory level, or even unquestionably at a superior level, most, in fact, do not so perform and either voluntarily or involuntarily leave school. . . . It does not follow that increased retention and graduation and a comparable decrease in attrition will result by increasing the level of prior academic performance for ad-

> mission or complicating the quantitative approach to admission by way of prior grades and test scores.
> [Huber, 1971, pp. 20-1]

These conclusions, based primarily upon the studies referenced in the chapter as well as in Appendix B, support the notion of a study which is macro in nature. Such a study is one which examines class and institutional characteristics in lieu of studying each individual student where an attempt is made to determine whether or not said student will drop from the university. Such a macro study should expose determinants of attrition rates.

Educational Production Functions

Why Investment?

For the purposes of this dissertation, higher education is treated as an investment good. Chapter I outlined the joint products as graduates (G) and nongraduates (N). As already stated in that chapter, Becker (1964, p. 93) suggests that some college, referring to dropouts, is a relatively unprofitable investment. Should education be considered a consumption good, the output N would have no social value, only value to the consumer. In spite of the requirement that education be an investment good to permit the use of N as one of the joint products, evidence supportive of the fact that education is either a consumption or investment good is presented.

Blaug (1970, p. 17) says that in Keynesian theory, education is a consumption good, not an investment, because it is paid for by the household or the government on behalf of households. The Keynesian definition is dependent upon the behavior of the expenditure units, not on the nature of the good purchased. Generally consumption means exhausted in the present calendar year, investment means using current output to generate higher *output in the future* (Blaug, 1970, p. 18).

Veblen expressed it this way.

> The quasi-peacable gentleman of leisure, then, not only consumes of the staff of life beyond the minimum required for subsistence and physical efficiency, but his consumption also undergoes a specialization as regards the quality of goods consumed. He consumes freely and of the best, . . . In the process of gradual amelioration which takes place in the articles of his consumption, the motive principle and the proximate aim of innovation is no doubt the higher efficiency of the improved and more elaborate products for personal comfort and well-being. But that does not remain the sole purpose of their consumption. The canon of reputability is at hand and seizes such innovations as are, according to its standard, fit to survive. Since the consumption of these more excellent goods is an evidence of wealth, it becomes honorific; . . .
>
> [Veblen, 1965, pp. 73-88]

Human Capital Theory challenged these education-as-a-consumption ideas to make education an investment. (See Chapter I.) "Human Capital is the present value of past investments in the skills of people, not the value of people themselves."[15] Of course, all who have written on the economics of education using the production function approach in the interest of broad public policy are treating education as an investment.

> A higher wage for educated labor would reflect an ex ante belief in the greater productivity of the worker with more education (and ex post varification of this) over productivity of the average worker drawn from the labor pool.
>
> [Fuller, 1982, p. 17]

Fuller (1982, p. 41) further asserts that if schooling imparts productivity differences, the graduates' first full-time job should be directly affected by the level of education attained.

Comments such as: "Education is productive," or "Individuals do not appear to attend school primarily for consumption purposes," and "School attendance appears to be justified by its ability to affect wealth,"[16] should leave absolutely no doubt in the mind of the reader that the author of those statements favors education as an investment.

Still others define the educational production process in explicit terms, an investment process by which inputs (student, teachers' knowledge and skills, and educational materials) are brought together and transformed into a final product--the graduate.[17]

Arguments can be dynamically presented to support education as either consumption or investment. What it really comes down to is an ideological argument based on definitions and need of the one presenting the argument, and definitions are used in an attempt to justify the approach of each particular author. However, if one is concerned with public policy, then education becomes an investment and the use of a production function requiring investment connotations is appropriate.

Forms of the Function

A function is a quantitative approach to describe the relationship between one value which depends on another value or set of values. The general notation in the educational context is: $E=f(X_i)$, where X_i = resources used in educational production, E = education, and $f(X_i)$ takes on certain characteristics such as monotonic, continuous, and differentiable throughout.[18] But it is not really as simple as that.

> We face a pervasive ignorance about the production function of education, that is, the relationship between school inputs, on the one hand, and school output as conventionally measured by achievement scores, on the other.
> [Blaug, 1970, p. 269]

This pervasiveness aside, most studies utilize some simple form of an additive, linear type function, whether that be log-linear or otherwise. Bowles (1970, p. 16) prefers the simple linear additive form:

$$[1] \quad A_i = b_0 + b_1X_{1i} + b_2X_{2i} + \ldots b_zX_{zi} + u_i,$$

where A_i = output measure of i^{th} student,

$b_0 \ldots b_z$ parameters of the production function to be estimated,

X_{zi} amount of input z devoted to student i's education, and

u_i the disturbance term.

Edward Lazear (1977, p. 577) prefers the log-linear form for the educational production function. But, in either case the method generally employed is regression analysis.

In spite of the common approach used, what really happens as a result of the educational process remains a puzzle.

> . . . cross-sectional data can tell us little about how a dynamic system has worked in the past or how it could be made to work in the future. The more complex and more dynamic the system, the less likely are conventional analyses to yield reliable inferences about it. Regression analysis fails to detect dynamic relationships, for that reason, if independent variables change over time in relation to others, the direct effects on the dependent variable are likely to be under-estimated.
>
> [Luecke and McGinn, 1975, p. 347]

For that reason, even though the commonly accepted form of linear additive is used through the most generally accepted method of multiple regression, a great deal of care must be adopted when generalizing from results obtained on any study.

Inputs and Outputs

Given the generally accepted form of the educational production function, it becomes imperative to examine in detail the inputs and outputs used in this production process. Efforts to measure the relationship between inputs and outputs began in earnest in the late fifties (1950s).[19] A description of typical inputs will lead this section. Outputs will follow.

Inputs

Inputs in the educational production function can be classified into any one of a number of ways. Fixed inputs and policy inputs result from one such method of classification.[20] Student characteristics, school-related factors, and other community influences result from a second.[21] And any combination of these is a possible third.[22] Which classification is used is really immaterial. What is important here is the specific variables used. On that ground, most authors agree and they include such variables as are found in Figure 3.

The major problem comes in the measurement of some of these variable inputs. It is obvious that some are clear-cut and well-defined. Others require the use of a proxy measure.

> All inputs must be measured in physical terms making allowance, where necessary, for any changes in quality. Since the inputs are heterogeneous, it is impossible to find a single physical unit in which they can all be expressed.
> [Blaug, 1970, p. 273]

With other variables, the problem becomes one of aggregation.

> This problem is often dealt with by aggregating several separate variables into a single input measure, for example, when expenditures per pupil are used to measure school inputs. The expenditure measure is an aggregation of a variety of separate dimensions of input: teacher experience, degree status, starting salary, and the teacher-to-pupil ratio. The appropriateness of the aggregation depends upon the policy question being asked.
> [Heim and Perl, 1974, p. 4]

Outputs

The Public Services Laboratory of Georgetown University defines educational outcome as the result of learning which affects (1) the advancement and development of the individual, (2) the quality of living of the individual in the social community in which he functions, and (3) the development of the society in which the individual lives, that is, Typical Input Measures

School Bldgs. (physical size of campus)	Age
Student independent study time	Race
School size (number of pupils)	Student I.Q.
Teacher socioeconomic status	Library size
Teacher verbal ability	Social status
Teacher degree status	Administrative
Pupil-teacher ratio	Father's income
Teacher experience	Father's education
% of male teachers	Mother's education

Figure 3. Typical Inputs for Educational Production Functions

its economic, social, and political system.[23] In spite of the guidance, there is no concensus on what the output of education is or what it should be, so most analyses of education as a production process focus on ability or achievement tests as a measure of school output.[24] At a level below the university, a battery of tests comprised of (1) Iowa Tests of Basic Skills, (2) Iowa Tests of Educational Development, (3) Stanford Achievement Test, and/or (4) college entrance tests (ACT and SAT) have typically been used.[25] These standardized examinations are mostly generally used because they are (1) single vectored, (2) quantifiable, and (3) correlated with most other desirable features of education.[26] As a result, most authors use these exams for an output measure even though they are critical of them.

There are a few researchers who have also considered other measures of output such as student attitudes, attendance rates (Katzman, 1971), and college continuation or dropout rates. Some of these studies are examined later in the chapter with other studies being detailed in Appendix C. Figure 4 presents a list of "ideal" types of outcome measures.

But what output measures have been used at the college or

Types of Outcome Measures[27]

1. Measures of Economic Development
2. Measures of Work Skill
3. Measures of Cognitive Skills
4. Measures of Societal and Political Outcomes
5. Measures of Advance in Opportunities for the Rural Population and Other Target Groups
6. Measures of Family, Village, and Urban Levels of Knowledge, Skills, and Attitudes

Figure 4. Ideal Outcome Measures

university level of production. The major problem in this area is the definition and measurement of outputs, the result being that very few studies on the production function of higher education have appeared in the literature. The only one with a qualitative dimension was done by Alexander Astin in 1968.[28] He used the Graduate Record Examination (GRE) scores as a measure of output.[29] His study is one which is examined in greater detail in Appendix C.

Some of the traditional measures of output, at whatever level of education under study, are clearly input measures, others are an attempt to move away from inputs to process level criteria, while still others are first attempts to measure output in quantity terms such as enrollment rates and dropout rates.[30]

> Usually, the outcomes of higher eudcational institutions are judged in terms of institutional 'quality.' Quality is measured by characteristics such as faculty and staff salary scales, faculty-student ratios, percentage of faculty with a Ph.D., number of library books, square feet of building space, entrance examination scores of students, amount of endowment, and so on. These are all inputs; they are not outcomes.
> [Bowen, 1981, p. 53]

It was established in Chapter I that education produces multiple output. Elchanan Cohn (1979, p. 171) does not precisely contradict that conclusion but rather adds fuel to the fire in the controversy already existing over output measures by his pronouncement that an analysis of all outputs is too cumbersome and unnecessary since the proxies which must inevitably be chosen are likely to provide as much information as the entire output set and at a lesser research cost. This dissertation does not put the controversy on output measures to rest, but it does treat the educational output as multi-output and more precisely as a joint product output.

Educational Production Function Studies

Serious efforts to measure the relationship between inputs and outputs began in the mid-1950s. A partial list of the studies which have been performed is presented first with bits of information about the contributions of that particular study.[31] More detailed research efforts of a select few authors of production function models and their conclusions are presented in Appendix C.

In 1956, William G. Mollenkopf and S. Donald Melville did research for the Educational Testing Service. It is generally recognized that this is the first large-scale input-output study on the economics of education. It is also one from which many of the later studies have profited. They used 9,600 ninth grade students from 100 public schools and 8,357 twelfth graders from 106 public schools, all of which were selected from across the United States. They used 34 independent variables, among them were shcool, non-school, and peer group influences. The measure of output was a specially designed test. Only one school factor was consistently correlated (in a statistically significant sense) with the test results using simple Pearson Correlation techniques. That school factor was library and supply expenditures, while such variables as the number of special school personnel, class size, and student-teacher ratio all showed some influence.

In 1959, Samuel M. Goodman conducted the New York Quality Measurement Project (NYQMP). This was an attempt to control for the affects of parents' socioeconomic status. It was a study of 70,000 seventh and eleventh graders from the state's public schools. Classroom atmosphere and teacher experience were both found to have an effect on the output--student achievement.

In 1962, James Alan Thomas performed a study on data collected for Project TALENT. It utilized 200 schools in a national sample. His was the first major study to rely on regression analysis techniques for the primary means of statistical analysis. From a list of twenty-seven input variables, Thomas found three school variables to be of particular importance--starting teacher salaries, teacher experience, and the number of books in the school library.

In 1965, Charles S. Benson and some associates conducted a study on school effectiveness for the state of California. In that effort, they controlled for student background characteristics and found that a significant positive relationship existed between teacher salaries and student achievement.

In 1966, James S. Coleman and his associates performed the "Equality of Educational Opportunity" survey, commonly referred to as the "Coleman Report." This study is the benchmark of educational production functions and as such it is the most hotly debated one as well. They used data from approximately 645,000 individual students selected by type and location of elementary school. Ninety-three separate input variables were used along with an outcome measure consisting of ten test scores in an attempt to determine the school and non-school factors related to student achievement. Of the school factors, teachers' verbal ability seemed to be the most important even though very little statistical association between these variables in comparison to non-school variables was discovered. Numerous studies have subsequently been performed on the data from the Coleman Report. One such study, that by Bowles (1970) is covered subsequently in greater detail in Appendix C.

In 1967, Herbert Keisling covered another aspect of the NYQMP by assessing input and output in varying kinds of school districts in New York. Looking at large and small, rural and urban elementary schools, he found significant relationships between the cognitive output measures and student-teacher ratio as well as expenditures for books and supplies. He reported that none of the other variables was uniformly important.

In 1968, Elchanan Cohn used the "incremental change in scores" on the Iowa Tests of Educational Development as an output measure for a sample of 377 Iowa high schools, the majority of which were public secondary schools. A significant negative relationship was found between the output measure and two input variables--number of teachers' college credit hours and number of discrete teaching assignments per teacher. A significant positive relationship was found to exist between said output and the median teacher salary.

In 1968, Richard Raymond used college freshman grades and composite scores on the ACT as the output measure along with precollege school and non-school inputs. The non-school inputs were derived from 1960 census data for various West Virginia counties. Teacher salary was the only school component found to be statistically significant in the positive direction. The student's elementary school teacher salary was the most potent predictor.

In 1969, Thomas G. Fox reported on thirty-nine Chicago schools. He used two output measures--reading scores and retention rates--along with a somewhat different set of school inputs. Among those inputs were such things as school building utilization rate, capacity and age of buildings, book expenditures, man-years of teacher and staff time committed to the school, student time in specific vocational courses, and employment status of students. Book expenditures and building capacity were the only two insignificant variables. The greatest impact of this particular study is that it presented the first simultaneous equation model of educational production.

In 1970, Eric Hanushek did research in a single school district in California. His entire analysis proceeded from data at the individual student level of aggregation. He subdivided the data into groups by Mexican students and white students with a further stratification depending on student's father's occupation--manual labor or not. He used the Scholastic Aptitude Test score for the output measure and failed to find the relationship which others had found between the two most commonly used school input factors and the individual student level output.

These studies provide a representative flavor of educational production function studies which have typically been performed to study the economics of education. In addition to those already presented here, Appendix C details five other authors' studies by specifically describing their inputs, outputs, methodology, and results. Table 7 further provides a summary highlighting all of the major educational production function studies referenced in either portion of this

Table 7--Summary of Educational Production Function Studies Reviewed

Researcher	Project Name	Significance or Method Used	Level of Education	Size of Study	Output Used	Significant Results
(1) Mollenkoph & Melville (1956)	-	Pearson Correlation	9th grade & 12th grade	9,600 & 8,357 students	special test	1) First large-scale input-output study on education 2) Library and supply expenses correlated with output results
(2) Goodman (1959)	NYQMP	-	7th grade & 11th grade	70,000 students	Student Achievement Test	1) Classroom atmosphere 2) Teacher Experience
(3) Thomas (1962)	Project TALENT	Regression Analysis	elementary & secondary	200 U.S. schools	Student Achievement	1) Starting teacher salaries 2) Teacher experience 3) Number books in library
(4) Benson (1965)	-	-	elementary & secondary	California schools	Student Achievement	1) Teacher salaries
(5) Coleman (1966)	Coleman Report	Stepwise Multiple Regression Analysis	elementary & secondary	645,000 students	Ten test scores including a nonverbal skill	1) Large sample size 2) Large number of variables 3) Indictment of school effectiveness in comparison to non-school factors

Table 7, cont.

Researcher	Project Name	Significance or Method Used	Level of Education	Size of Study	Output Use[1]	Significant Results
(6) Reisling (1967)	**NYQMP**	Rural to Urban Comparison	7th grade & 11th grade	70,000 students	Cognitive Student Achievement	1) Large and small, rural and urban school systems 2) Large negative relation between output and student-teacher ratio 3) Large negative relation between output and expenditures for books and supplies
(7) Cohn (1968)	-	Incremental Achievement	Public High Schools	377 Iowa Schools	Incremental Scores on Iowa Tests of Educational Development	1) Negative relation between output and number of teacher's college credit hours 2) Negative relation between output and number of discrete teaching assignments per techer 3) Positive relation between output and median teacher salary
(8) Raymond (1968)	-	-	Precollege	Instate Students who entered W. Virginia Univ.	College Freshmen grades and ACT scores	1) Teacher salary significant predictor of output 2) Student's elementary school teacher salary most important variable

Table 7, cont

Researcher	Project Name	Significance or Method Used	Level of Education	Size of Study	Output Used	Significant Results
(9) Fox (1969)	-	First Simultaneous Model	Precollege	39 Chicago Schools	Reading test scores and retention rate	1) Book expenditures and building capacity were the only insignificant input variables
(10) Hanushek (1970)	-	minority comparison to whites	Secondary education	1000 California Students	SAT scores	1) First study to procede entirely from individual student level of aggregation 2) Compared minority Mexican Americans with whites 3) Teacher experience and teacher education level not significantly related to output
(11) Bowles (1970)	-	comparison of 3 samples	Data for Coleman Report 12th grade	1000 Black U.S. 1000 North U.S. 1000 South U.S.	Verbal Achievement Test Score	1) Estimated effects of different schools are limited 2) Uniform 10% improvement in all school inputs--raise achievement by 5.7% 3) Successful identification of many school inputs which do affect student learning

Table [illegible], cont

Researcher	Project Name	Significance or Method Used	Level of Education	Size of Study	Output Used	Significant Results
(12) Burkhead, Fox, & Holland (1967)	-	Correlation in comparing three Samples; Dropouts as output	Project TALENT, High Schools	[illegible] schools 49 Chicago 22 Atlanta	Reading & Verbal Skills, Dropouts	1) Major determinants of school performance were factors external to schools themselves 2) High negative correlation between family income and dropout rate
(13) Katzman (1971)	-	Regression Analysis Then Stepwise Regression	Boston City Elementary Schools	56 schools	Cognitive Abilities, Retention, Academic Achievement	1) No input was consistently significant 2) Teacher turnover had negative effect on performance 3) School resources affect retention
(14) Link & Ratledge (1979)	-	Tests for Student Perceptions of Expectations	4th grade	500 students	Reading Achievement	1) Student perceived expectations of parents and teachers made significant contribution to reading test scores
(15) Astin (1968)	-	Higher Education Production, Three-stage Step-wise linear regression	University	699 students	GRE test results	1) No clear-cut pattern of institutional characteristics which either fosters or inhibits student achievement

dissertation

Summary and Critique

Education at the university level can properly be viewed as either a consumption good or an investment. A great deal of emphasis has been placed on the production of education since the mid 1950s. Most of the production function studies have been accomplished for elementary and secondary schools with very few appearing on universities. (See Table 7 for a summary of major educational production function studies.) The results of production function analysis are most generally evaluated in two ways. First is the magnitude of the effect which the input variable has on the specified output. The second evaluation is usually the statistical significance of the estimated effect.[32]

The single most frequent critique of the educational production function studies which have been performed and the methodology in general appears to be the specification and measurement of output. Most authors agree that outcome measurement is essentially a matter of measuring what individuals know or what they have learned; i.e., testing knowledge, skills, attitudes, and attributes. Such testing is especially important for young children because substitute measures are harder to develop.[33]

> Standardized testing instruments are not always available and are not always appropriate for all purposes. At the classroom level, clearly evaluation is needed throughout the period of instruction, not merely at the end. . . . Teachers must rely on observation and recordkeeping to evaluate important student behavior such as initiative, self-direction, curiosity, creativity, leadership skills, organization of materials, and use of the library.
> [Public Services Laboratory, 1975, pp. III:12-3]

In spite of all the work which has been done and the conclusions reached and primarily because of the difficulty in measuring output, Blaug makes the following statement:

> It is clear that productivity measurement or cost-effectiveness analysis amounts to little more than a framework for research, challenging us to explore new ways of converting quality into quantity and directing our attention to critical gaps in knowledge . . . . The magic numbers that have so far been generated must be regarded as purely provisional, calling for and indeed inviting falsification by further attempts at "measuring the unmeasurable."
>
> [Blaug, 1970, p. 281]

Chapter Summary

A large number of those writing about the economics of education have been referenced in this chapter and in Appendices B and C. Even then, that number only approaches a fraction of the whole. Further works are available in another detailed survey by Siegfried and Fels (1979). The reasons for such an extensive review were threefold. First was to present an adequate cross section of the various methodologies previously employed. Second was to provide a feel for the types of inputs and outputs used in each of the studies. These studies provide the basis for the general methodology and the inputs used in this dissertation. The third reason for such an extensive review was to provide a basis for the measurement of attrition as an output through the educational production function literature. That necessitated reviewing both attrition literature as well as that pertaining to educational production functions.

Attrition of students was detailed first. The main conclusion is that of every 100 students entering college, 40 will never graduate. Reasons for the dropout of college students include financial difficulties and a definite loss of interest or boredom with the university routine which is most usually the result of a serious lack of identification with the affiliated institution.

A section on the educational production functions brought the chapter to a close. Many of the production function studies were mentioned briefly with several being detailed in Appendix C. Of all those efforts, only two or three have dealt with attrition, and those were consistently at a level below the university. Only one educational production function study dealt with university production--that of Astin--and he did not address attrition. Those facts open the door for this dissertation on attrition at a university using the educational production function approach.

Now that the background and the foundation have been established, the theory and methodology for this dissertation are ready to be developed in detail. That detail follows in Chapter III.

Notes to Chapter II

1. See Lawrence A. Pervin, Louis E. Reik, and Willard Dalrymple, eds., The College Dropout and the Utilization of Talent, Princeton, New Jersey: Princeton University Press, 1966, 7.

2. Vincent Tinto, "Dropout from Higher Education: A Theoretical Synthesis of Recent Research," Review of Educational Research, 45, (Winter) 1975, 98. See also: Philip E. Beal and Lee Noel, What Works in Student Retention, Report of a joint project of the American College Testing Program and the National Center for Higher Education Management Systems, 1980, 1; Cathleen Bower and Edward Myers, A Manual for Conducting Student Attrition Studies in Institutions of Post-secondary Education, Technical Report No. 74 of National Center for Higher Education Management Systems and Western Interstate Commission for Higher Education, Boulder, Colorado, 1976, 2; Robert E. Iffert, Retention and Withdrawal of College Students, U.S. Department of Health, Education, and Welfare Bulletin #1, Washington, D.C.: U.S. Government Printing Office, 1958; Frank B. Jex, A Study in Persistence: Withdrawal and Graduation Rates at the University of Utah, Counseling Center Research Report 12, University of Utah, 1961, 1; and Cash Kowalski, The Impact of College on Persisting and Nonpersisting Students, New York: Philosophical Library Inc., 1977, 1-2.

3. William T. Gustavus, "Successful Students, Readmitted Students, and Dropouts: A Comparative Study of Student Attrition," Social Science Quarterly, June 1972, 53. The title alone assigns a stigma to "stopping-out" of college and definitely differentiates between the three possiblities facing a college student; (1) persist, (2) drop and never return or be readmitted, and (3) drop but later get readmitted and then persist. Transfers could fit either category (1) or (3) whichever applies to the continuity of their education.

4. Donald H. Ford and Hugh B. Urban, "College Dropouts: Successes or Failures?" in Pervin, et al., (1966), 83-106.

5. Robert Cope and William Hannah, Revolving College Doors, New York: John Wiley & Sons, Inc., 1975, 6. See also Kowalski (1977), 1-2.

6. Bower and Myers (1976), 2.

7. Cope and Hannah (1975), 3, say that as few as 13 percent will graduate in four years. Gustavus (1972), 136, says only 50 percent will graduate in four years. Jex (1961), 2-8, studies show 20-40 percent graduated in four years. For the Class of 1954, public institutions nationwide, 33 percent made it in four years. For the Class of 1954, public and private institutions nationwide, a total of 39.5 percent completed college in four years.

8. See A. W. Laird, "Dropout: Analysis of High Aptitude College Students - Western Kentucky's Search for Clues to this Problem," Western Kentucky University Faculty Research Bulletin, 95. Ref in Kowalski (1977), 3. See also Iffert (1958), 4, 17-8; and Pervin, et al., (1966), 7.

9. Such feelings of failure were referred to earlier in Chapter II. Supported by Tinto (1975), 94-7.

10. See Astin (1975), 14, Cope and Hannah (1975), 16-7; Iffert (1958), 91, and Kowalski (1977), 32-3.

11. The overall Iffert ranking was developed through combining the two financial categories on an average basis and then combining men results with women results in a similar weighted average fashion to account for the numbers of men and women in the survey.

12. See D. M. Knoell, "A Critical Review of Research on the College Dropout," in Pervin, et al., (1966), 63-5. Also see Kowalski (1977), 32-3.

13. See Chapter I, 11-2 for detail.

14. See Tinto (1975), 94.

15. See Blaug (1970), 19.

16. See Edward Lazear, "Education: Consumption or Production?" Journal of Political Economy, June 1977, 85, 571, 588.

17. See John Heim and Lewis Perl, The Educational Production Function: Implications for Educational Manpower Policy, Institute of Public Employment, New York State School of Industrial and Labor Relations, Ithaca: Cornell University, 1974, 1. See also Henry M. Levin, "Concepts of Economic Efficiency and Educational Production," in Joseph T. Froomkin, Dean T. Jamison, and Roy Radner, eds., Education as an Industry, National Bureau of Economic Research, Cambridge: Ballinger Publishing Co., 1976, 154.

18. Lazear (1977), 572.

19. See Elchanan Cohn, The Economics of Education, Cambridge: Ballinger Publishing Co., 1979, 174.

20. Heim and Perl (1974), 9-13.

21. Cohn (1979), 164.

22. Family background characteristics are included by Rex Fuller (1982), 22. As already outlined in Chapter I, this effort uses two categories of input. They are student input (defined by class characteristics) and institutional input (defined by some specific institutional characteristics). The reason for the approach is two-fold: the study is designed to be macro in nature; and the interest in examining class input, scale of operations, and technological (university) impact on attrition at universities.

23. See A Guide to Educational Outcome Measurements and Their Use, a series of six seminars, Washington D.C.: public Services Laboratory, Georgetown University, Selma J. Mushkin, Director, November 1975, I:7.

24. Heim and Perl (1974), 4. Also see Eric A. Hanushek, "Conceptual and Empirical Issues in the Estimation of Educational Production Functions," The Journal of Human Resources, Summer 1979, XIV, 354-5; and J. A. Kershaw, "Productivity in American Schools and Colleges," in M. Blaug, ed., Economics of Education, II, Baltimore: Penguin Books Inc., 1969, 305.

25. See Cohn (1979), 169.

26. See Kershaw (1969), 308.

27. Figure 4 was adapted from the Public Services Laboratory, A Guide to Educational Outcome Measurements and Their Use, Figure I-5, p. 14.

28. See Cohn (1979), 188.

29. See Alexander W. Astin, "Undergraduate Achievement and Institutional 'Excellence'," Science, August 16, 1968, 161, 661, for a detailed description of his study.

30. Public Services Laboratory (1975), I:13.

31. The list of production function studies in this chapter, along with a brief extract of each was taken primarily from Elchanan Cohn (1979), 174-87. Subsequent studies examined in greater detail have their own references.

32. See Heim and Perl (1974), 5.

33. See Public Services Laboratory (1975), III:8.

CHAPTER III

THEORY, MODELS, and HYPOTHESES

Introduction

Chapter I argued that the instruction portion of a university's output is, in effect, multi-product. That multi-product output is examined here in Chapter III using graduates and nongraduates as two separate outputs although many other classifications are possible. The chapter begins with a detailed review of the theory behind multi-ware production. That theory is specifically applied to the problem of attrition at universities. The models are then developed. A section containing hypotheses statements will conclude the chapter.

Theory

Multi-Products (Multi-Ware) Production

Before proceeding it is essential to have clearly in mind what is meant by multiple products and joint products. Multiple products are a reality for most firms which are in the business of producing goods. These firms produce a multiplicity of goods. Everyone agrees that General Motors is a multi-product firm. They are multi-product because they produce locomotives, cars, and trucks and each is produced at a plant separate from the other plants. Therefore, GM is able to assign and separate all inputs to the respective output in advance of the actual production process. In the truck plant, both GMC and Cheverolet trucks are produced. Assume they come off of the same assembly line.

Even though that be the case, it is still possible to determine which raw materials go to which vehicle, but now management of the plant and other plant resources are shared between the two products. So at least some inputs are shared while the products are still separable. The inputs are still separable in terms of the share time going to each product. Thus, the GM truck plant is still producing a multiple product output.

Because the truck plant is still multiple product, what are the features that describe and define a joint output?[1] The diagram in Figure 5 depicts the four possibilities for the input-output relationships. To qualify as a joint product, the inputs are shared by the products and the joint products are simultaneously or jointly produced from the same inputs by a single production process.[2] Allocation of each input is not made to each output separately. Thus, a multi-product production function need not exhibit jointness of production. Rao (1969, p. 737) makes this difference explicit when he writes, "The case of joint production is a technological phenomenon, . . . all products are produced in one production process."

Joint Products

An example of a joint product process is ore mining. After taking the ore from the ground and performing certain processing procedures,

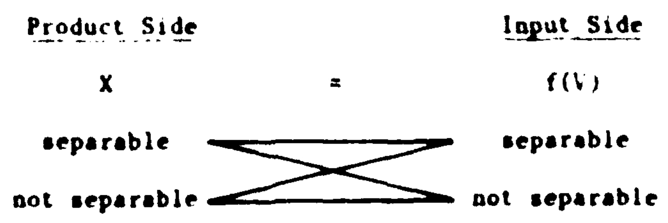

Figure 5. Multi-Products Possibilities of Separability

there may result several products jointly. During the process, much of the input cannot be specifically assigned to any particular output. Neither side of Figure 5 is separable--a joint product. Another example is the chairmaker briefly addressed in Chapter I. Assume his multiple output is good chairs and weak chairs. From his joint production function, he will know how many of each he will produce from given inputs. The degree of quality control is part of his production function. There may exist certain hidden defects which in effect cause weak chairs to occur along with the good chairs. The chairmaker cannot distinguish which input will go to which product but he can determine how much of one product will be built given the batch of lumber. The case is inseparable on both the input and output sides and thus a joint product process.

If there exists some sort of technical relationship between several products because there are certain factors which can or must be used jointly, or because certain factors can be used alternatively for one output or another, these products are technically connected.[3] In the general context, because a multi-ware production process is in evidence, the production law cannot be studied separately for each product but must be studied simultaneously for all connected products. The production system may consist of several (u) different ways or conditions of production and might be of the form shown in equation [2].

$$
[2] \quad \begin{aligned}
&F_1(X_1, X_2, \ldots X_m; V_1, V_2, \ldots V_n) = 0, \\
&F_2(X_1, X_2, \ldots X_m; V_1, V_2, \ldots V_n) = 0, \\
&\quad\vdots \\
&F_u(X_1, X_2, \ldots X_m; V_1, V_2, \ldots V_n) = 0,
\end{aligned}
$$

where X_m = m outputs or products,

V_n = n inputs,

F_u = u production relationships,

and the u equations are assumed independent of each other. Thus there are u production conditions.

Therefore, m products, n factors, and u product relations are defined. Frisch calls the difference between m and u, assortment,[4] $a = m - u$. By assortment, he means the degree of freedom of choice among connected products. If, for example, $m = 2$ and $u = 1$, then there is one degree of freedom over the product mix, given the inputs. For a single product production process, $m = u = 1$, or $a = m - u = 0$!

In the following statement, Frisch refers to a further subset of the technically connected products.

> Irrespective of the degree of assortment $a = m - u$, we can enquire whether, from the given u relations, it is possible to deduce some, and if so how many, which only link together certain product quantities, these relations containing none of the production factors. These relations are pure product bands; i.e., they are factor free. In other words, they hold good irrespective of what the factor quantities may be. If the number of such relations is C, we say that the degree of coupling--or more precisely the degree of product-coupling for the multi-ware production in question--is C.
> [Frisch, 1965, p. 270]

It is therefore self-evident that C is independent of m, n, and u. For example, if X_1 and X_2 are joint outputs from a given set of inputs V_i ($i = 1, \ldots n$), X_1 depends on V_i, and X_2 depends on V_i also; then, $a = m - u = 0$. But, if X_1 and X_2 are independent of the set V_i, i.e., factor free, then X_1 and X_2 are coupled or related as pure product bands. That is, $X_2 = f(X_1)$ or implicitly, $F(X_1, X_2) = 0$, without V_i in F. Thus, C = 1 band. Coupling, therefore, represents a new and different aspect of the production structure. It varies in degree from no coupling to perfect coupling, where the exact nature of coupling is related to the degree of factorially determined multiple product production. Thus the concept of joint products is a subset of the notion of multiple products.

Factorially Determined Cases

If the factor quantities are given and all the joint product quantities are determined, the system of equations [2] previously outlined does not apply. The general system is known as the factorially determined production process. Given m products, the general factorially determined system of equations is characterized by a set of m product functions.

$$[3] \quad X_1 = X_1(V_1, \ldots V_n)$$

$$\vdots$$

$$X_m = X_m(V_1, \ldots V_n).$$

The degree to which the factors determine how X_i is related to X_j is the crux of the theory of coupling. The degree of assortment is equal to zero; i.e., $a = m - u = 0$. If the vector V is given, the vector X is given uniquely.

Factorially determined production is classified into separable (or noncoupled) and coupled. Coupled is further classified into perfect and less than perfect coupling. Separable is discussed first.

Separable Products

The purely separable case is one where the combination of the product quantities is no longer joint in the sense that the products all come from the same production process (and, therefore, from the same inputs). Equations [4] and [5] represent the multi-product ($m = 2$) case of pure separability.

[4] $X_1 = X_1(V_1, \ldots V_n)$

[5] $X_2 = X_2(V'_1, \ldots V'_n)$

where $V \neq V'$. This is illustrated by Figure 6.

Coupled Products

Coupled joint products is another special case of factorially determined production. As previously indicated, there are degrees of coupling related to the degree of factor determinateness. The general case of coupling can be represented by

[6] $X_1 = X_1(V)$

[7] $X_2 = X_2(V)$

where V represents the same inputs for both functions.

An example of the joint two product system where some degree of coupling occurs and one used by Frisch[5] is that of poultry and egg

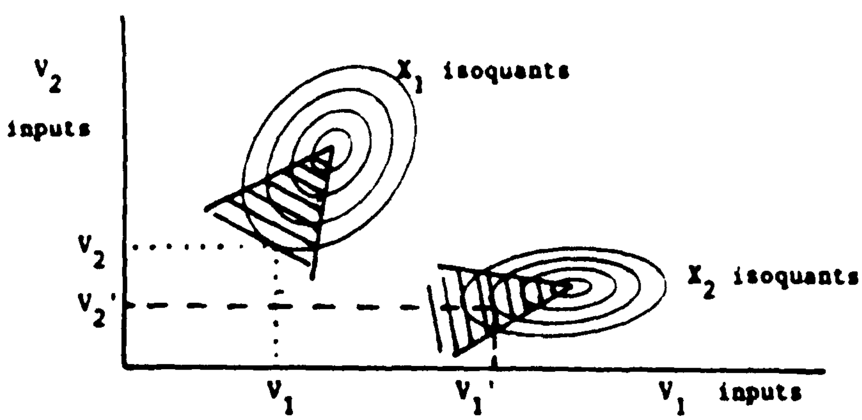

Figure 6. Perfectly Separable Case

production. There are two distinct products. In order to obtain the two products, certain production factors are required--certain materials and equipment, certain foods, and labor. When these factors are applied, in the same process, both products emerge, not only a certain quantity of eggs, but also a certain quantity of poultry. If the factor quantities are given, both product quantities are given as well. In this example, m = u = 2 and the degree of assortment, a = 0.

The ratio of the two product quantities is not necessarily fixed. In other words, coupling can be less than perfect. The ratio may indeed be altered within limits by means of suitable changes in the factor constellation; i.e., V_1, V_2, . . . V_n; for example, more rolled oats and less corn in feeding the chickens will change the ratio of the two quanties of output. Suitable changes in the input factors can place greater emphasis upon one or the other of the products. This is the case where the products are, to a certain degree separable. Figure 7 depicts the egg/poultry joint product factor relationship when less than perfect coupling exists. Here, X_1 = egg and X_2 = poultry depend on the same set of inputs V. And, when the combination of V_1 and V_2 is changed, then for a given quantity of X_1, X_2 varies.[6]

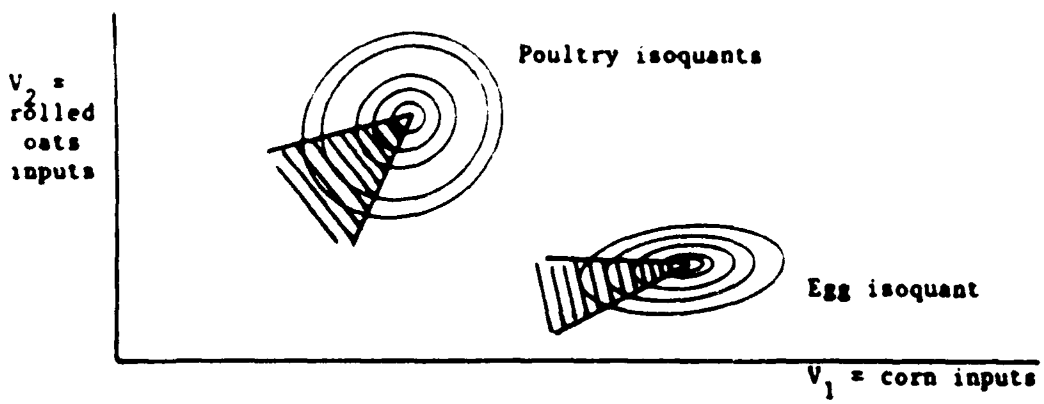

Figure 7 Bi-Products, Less Than Perfectly Coupled

Further, in the coupled case, the special functions can be of the form

[8] $X_1 = K_1 f(V_1, \ldots V_n)$

[9] $X_2 = K_2 f(V_1, \ldots V_n)$

where K_1 and K_2 are constants and $f(V_1, \ldots V_n)$ is the same function in both formulae. In this case the degree of coupling is $C = 1$ and the degree of assortment is $a = 0$. As indicated earlier, there is a pure product band relating X_1 to X_2. For example, we can assume that the quantity of cream (sometimes called butterfat content) bears a fixed ratio to the quantity of milk produced by a cow. A change in the factor quantities could perhaps be a change in feed or a slightly longer period of time between milkings, but changes always occur in such a way that the quantity of cream and the quantity of milk change in the same proportion. In this case

[10] $X_2 = KX_1$,

or Cream = some constant times milk, where K is the constant.

But coupling need not be that simple. The quantity ratio between the two joint products may be a function of the product quantities. The characteristic feature of this case of coupling is that one product is a well-defined function of another product where none of the factor quantities occur. As with the simple coupled case, $C = 1$ and $a = 0$, the characteristic feature appears as

[11] $X_2 = g(X_1)$,

or implicitly $F(X_1, X_2) = 0$. Equation [11] is contrasted with [10] above where the relationship is a constant. The example Frisch uses for this case of coupling is the relationship between gas, coke, and coal tar.

> These three products are linked together in such a way that the quantity of coke is a technically given function of the quantity of gas, and similarly that the quantity of tar is a technically given function of the quantity of gas; while the total product quantity--measured for example by the quantity of gas--is determined by the quantities of the factors.
> [Frisch, 1965, p. 271]

Here the number of production relations is three ($u = 3$). The number of products is three ($m = 3$). The degree of assortment is zero ($a = m - u = 0$). And the degree of coupling is two.

Figure 8 depicts the case of perfect coupling. It is the graphic illustration of the case where X_1 and X_2 bear a definite relation and that relationship is independent of the factor quanties. It is also fairly obvious that most joint products lie somewhere between Figure 6 (completely separate substitution regions) and Figure 8 (coinciding substitution regions).

Now that the definitions are established, the theory can be applied to the attrition problem at universities.

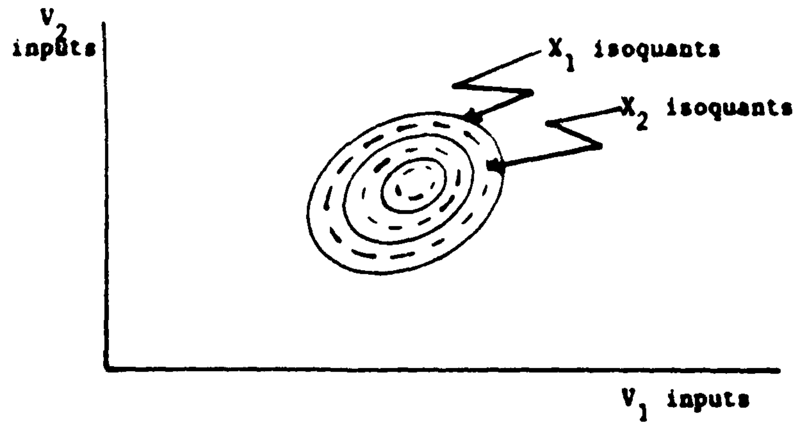

Figure 8. Bi-Products, Perfectly Coupled

Application of the Theory

When a university admits a group of students, unless it has knowledge of its joint production functions, it does not know with certainty how many will complete each year of school and how many will drop. Nor is it known which resources will be used by those completing or by those quitting school. Therefore, if the products are defined as educated finishers, those who complete each year of school and subsequently graduate, and educated dropouts, those who fail to finish a specified year of school and subsequently do not graduate, then the university production process is one of joint products.[7] Because both outputs can theoretically vary as inputs are varied, the production system is factorially determined. It then follows that the applicable system of equations for the joint product output of a university, where the outputs are defined as educated students who complete and educated students who drop, is depicted, in effect, by equations [6] and [7]. It is these two equations we wish to measure.

The example used earlier about the chicken and egg production is again beneficial to stress the points on the application of the joint product theory. A chicken farmer supposedly raises chickens for one of two reasons. One is the production of eggs, the other is the production of poultry. Having certain fixed facilities available for the short term, a certain quantity of chicks are brought to the farm for the sole purpose of meeting production goals. If the egg production goal is too high, and the number of chicks too small, eventually there will not be enough chickens to meet the egg production goals regardless of the quantity or quality of other inputs on the part of the farmer. Therefore, scale of operations is important. Now the quality of the chicken input is important because only female chickens lay eggs. Of course the farmer would certainly prefer all hens because both outputs would be available to every chicken, whereas with the scenario selected, male chicks have but one possible product, poultry. So there is concern about the quality of the batch of baby chicks input into the process.

How about the farm facilities and inputs? The main concern on the part of the farmer is to meet both production goals, eggs and poultry. By altering such input factors as quantity and type of feed, egg production can be fostered at the expense of fat, plump chickens for the poultry market and vice versa. So, a third concern is the technological process involved with the production itself, the institutional inputs. Note here that the main concern of the chicken farmer is not specifically with the production of each chicken, but rather with the macro production goals of the farm.

Now that the analogy is made, the parallels may be drawn. A university has two joint products, which for ease of identification here are referred to as completion and attrition. Goals can be established for each of the products, although once a goal for the number of educated students completing each year is established, the number of educated dropouts will be known. As with the farmer, the first concern is seeing that the scale of operations can be met. It would be foolhardy to have a goal of 500 students to complete the freshman year if only 485 students started that year.

The second concern is for the group of students brought into the university. The literature review in Chapter II indicated that a university does not have the ability to specify with complete accuracy, in advance, which entering student will be a part of which output, simply because it is not possible to accurately predict which student will drop out and which will persist. However, as with the chicken farmer, if the characteristics of the group as a whole change, there is the opportunity for improved possibility of meeting both production goals. Emphasis cannot lie upon every single student's input especially since even with the top twenty percent of a graduating high school class, nearly 31% of those going on to college drop out.[8] Therefore, the emphasis is macro. It is on the input characteristics of the group.

The third concern has to be with the institutional or the technological inputs. As with the scale of operations, the institution's main concern is macro--meet the production goals. One's first thoughts are that in a university setting where the output is people oriented, that concern is cold and impersonal. But, it is through the efforts of those who labor that ill chickens are nursed back to health and thus are able to contribute to production. The same principles apply to a university. It is the efforts of faculty and staff with individual students which contribute to the successful accomplishment of production goals.

Now the general equations for the bi-product or joint production process of universities are given by

[12] $X_1 = X_1(V_s, V_c, V_i)$

[13] $X_2 = X_2(V_s, V_c, V_i)$

where X_1 = output as defined by educated finishers,

X_2 = output as defined by educated (at least partially) quitters or dropouts,

V_s = scale input,

V_c = class characteristics or qualities, and

V_i = institutional inputs.

These are the production functions (which are assumed to exist) that are estimated in this dissertation.

The output measures along with the specific variables which are used to measure scale, class characteristics, and institutional inputs are specifically defined in the next section, Model Definition.

Model Definition

Essentially five models are presented even though the variables are the same for each model. The five are: one for each level of undergraduate college education and one aggregate, representing university output during the academic school year. Variables are outlined here only in enough detail to present the models while the specifics of variable definition are in Chapter IV.

Outputs

As it was previously shown in Chaper II, defining and adequately measuring the joint products is a most difficult task. Many indices of output measurement are available. (See the section on output of educational production functions in Chapter II.) Several such measures are here suggested as theoretical indices for the measurement of aggregate university output.

First are the raw numbers (N). During any school year, a college instructs on four levels of undergraduate education. At the end of that year, students have completed the freshman, sophomore, junior, or senior year. When measured in aggregate numbers of finishers, the output is the sum of all four levels of academic achievement. And during that same period, the joint product is the aggregate of nonfinishers, those who started a given level but dropped out during the year in question. The justification for breakdown by education level is found in the extremely disproportionate number of students who drop from school during the freshman and sophomore years. (See statistics on attrition in Chapter II).

A second possible index is the number of credit hours (SCH) completed by finishers and nonfinishers. Again, the index would be measured for each level. A third possibility is the grade point average (GPA) of each product, while yet a fourth is some combination of the first three, such as N x SCH x GPA. Only the first measure, N, is used in this study, although possibilities and justification can be offerred for implementation of other indices of output measure. So, the index of output as used herein is the number of educated finishers and the number of educated dropouts, and the joint products are defined theoretically as (1) those educated students who finish and (2) those educated students who drop out.

The reason for using the actual numbers of finishers and dropouts is one of necessity. As is discussed in Appendix A, an elicitation process is used to develop prior subjective estimates of the parameter values. It was determined that such a process would be extremely difficult to use unless notions of the joint outputs were fairly simple and well defined. While other indices have appeared in the literature, using numbers as indices in this study seemed to be a good first-approximation approach to a difficult problem.

The model now appears as

[14] $X_{fj} = x_{fj}(V_s, V_c, V_i)$

[15] $X_{dj} = x_{dj}(V_s, V_c, V_i)$

where X_{fj} = number of finishers of level j, j = 1 to 4, for a particular schoolyear,

X_{dj} number of nonfinishers (dropouts) from level j for the same year and both equations have the same factor quantities, V_s, V_c, and V_i.

The total number of such pairs of equations is five, one for each level (freshman to senior) and one aggregate to show university total output by finishers and nonfinishers for a whole year. Since the number of entering students is equal to the number of finishers plus dropouts, equations [14] and [15] are alternative estimates of the joint outputs.

Now that the models have been outlined and output measures specified, the inputs are specifically identified and defined.

Inputs

V_s represents the scale of operations for the university. Only one variable is used to measure scale and that is the number of students (NS) entering school for each grade level in the fall at the beginning of the school year.

V_c represents the input class characteristics. Many such attributes are available and measurable for individuals but such measures for a class are more difficult to obtain. The variables used to measure class characteristics are: mean entrance score (SC), a leadership measure (LD), and physical abilities based on several exercise test results (PH). A fourth measure of the class characteristics is the range of entrance scores (RS) for each entering class.

V_i are the institutional inputs. Those selected for examination here are faculty quality (FQ), faculty experience (FE), and the student-faculty ratio (SF).

Because of the lack of variation for some of the input variables, a difference in admittance policy of the UofU,MBA program, and the quantity of available data, there is some deviation from the variables as outlined above for the USAFA. The primary difference is the absence of emphasis upon leadership and physical measures. In lieu of those inputs, the average age of entering students (AA) is used. In addition, no institutional inputs are used for the UofU,MBA. Differences in measurement of the input variables are subsequently covered in Chapter IV.

Equations

The specific equations estimated for the USAFA and the UofU,MBA are presented here.

USAFA

$$[16] \quad N_f = \beta_1 NS + \beta_2 SC + \beta_3 RS + \beta_4 PH + \beta_5 LD + \beta_6 FQ + \beta_7 FE + \beta_8 SF + \mu_j.$$

$$[17] \quad N_d = \gamma_1 NS + \gamma_2 SC + \gamma_3 RS + \gamma_4 PH + \gamma_5 LD + \gamma_6 FQ + \gamma_7 FE + \gamma_8 SF + \epsilon_j.$$

Since, as previously indicated, [16] and [17] are alternatives, [17] can be rewritten as

$$[17'] \quad N_d = (1-\beta_1)NS - \beta_2 SC - \beta_3 RS - \beta_4 PH - \beta_5 LD - \beta_6 FQ - \beta_7 FE - \beta_8 SF - \mu_j.$$

Essentially, this represents a test to determine whether or not the ratio N_f/N_d is perfectly coupled, that is, whether or not $N_f/N_d = K$, a constant.[9] In general, the ratio of [16] to [17] is a function of the form

[18] $N_f/N_d = k(NS, SC, RS, PH, LD, FQ, FE, SF)$,

where now k is a function which is homogeneous to the zero degree. That is, if all inputs in [16] and [17] are increased by λ percent, then, the ratio (N_f/N_d) is unchanged. But, if the inputs are increased by varying amounts, the ratio changes. An empirical form for [18] and the ratio of [16] to [17] is given by

[19] $N_f/N_d = \alpha_1 NS + \alpha_2 SC + \alpha_3 RS + \alpha_4 PH + \alpha_5 LD + \alpha_6 FQ + \alpha_7 FE + \alpha_8 SF + \epsilon_j^1.$

Equations [18] and the empirical form [19] are the same as that developed by Vinod (1968, pp. 329-30) in which he "measures the percentage change in the proportions in which any two outputs are produced (e.g., X_1/X_2) resulting from a one per cent change in any input." With the estimates of [16] and [17'], [19] is implicitly determinable. In this dissertation, [19] is not explicitly estimated, however, due to the elicitation problem alluded to in the section "Outputs" earlier in this chapter.[10]

The equations [16] and [17] are estimated five times, through the estimation of [17'], one for each undergraduate class year in progress and once for the aggregate university academic year output. Input variables are identical for equations of each specified level of education (representing class inputs) while N_f and N_d represent the number of students to finish or drop respectively. The error terms are μ_j and ϵ_j, j = 1 to 5.

$UofU_j MBA$

$$[20] \quad N_f = \beta_1 NS + \beta_2 SC + \beta_3 RS + \beta_4 AA + \mu_j .$$

$$[21] \quad N_d = \gamma_1 NS + \gamma_2 SC + \gamma_3 RS + \gamma_4 AA + \epsilon_j .$$

$$[21'] \quad N_d = (1-\beta_1)NS - \beta_2 SC - \beta_3 RS - \beta_4 AA - \mu_j .$$

Because the UofU,MBA program is a two-year graduate program and because it has such a relatively short life, equation [21'] is only estimated one time representing an aggregate academic year output.

Properties

In subjective statistical theory, β_i, and γ_i are not observable random quantities having a sampling distribution but rather nuisance parameters. They are useful, not in representing some measurable characteristic of the real university world, but in representing characteristics of the researcher's opinions (as evidenced by the included variables) about the observable and measurable independent and dependent variables. The researcher's opinions are further supplemented by the prior opinions of experts in the particular field under study.

Once the classical model is estimated using equations [17'] and [21'], the elicited prior opinions of the experts are brought to bear. The posterior mean of the distribution of the coefficients is a weighted linear convex combination of the prior mean and the maximum likelihood mean with weights proportional to the precision of each. Appendix D details the statistical properties and assumptions.

The properties of the joint product have briefly been mentioned and include:

1. Number of products = m = 2.
2. Number of product relations = u = 2.

3. Degree of assortment = a = m - u = 0.

The productivity of the university as defined here by the number of beginning students who complete the school year, must not be confused with efficiency of the university. Efficiency refers to the optimal combination of inputs to produce a given output at least cost. It is measured at a point in time.[11] Productivity here is measured between two calendar dates, the beginning of the school year and the ending thereof. The relationships developed between the inputs and the joint product outputs describes average behavior of a class of students. This average information may not be particularly useful in predicting how changes in inputs would affect the outputs.[12] Related to that is one of the disadvantages of the linearly additive educational production function; i.e., it provides a constant marginal product (MP) for each and every input independent of the level of that input.

Hypotheses

The hypotheses tested fit into one of two general categories. The first is the question of empirical validity for the methodology of using a joint product output. This is examined in the traditional sense by comparing the relative explanatory power of the determinants of the two dependent variables for each level of higher education as well as the aggregate university academic year output. The subjective statistical approach employed goes one step beyond the classical methodology and merges prior opinions of experts with the classical statistical results.

The second category posited relates to the models developed. The specific models allow examination of the three classes of independent variables for each level of education; i.e., scale of operations, class-year characteristics, and institutional inputs. By looking at attrition and completion in the factorially determined product relationship, light is shed on factors which lead to attrition from universities. It was shown earlier in Chapter III that since the k-function is homogeneous to the zero degree, the relative amount of attrition at a university will not change unless inputs are varied disproportionately. Thus, policy emphasis can be placed on those critical input areas to reduce said attrition.

In addition to the general categories outlined above, this effort explores the validity of using educated nonfinishers or dropouts as one output of higher education. Chapter II and Appendix C each contain a review of many authors who had performed work in the economics of education using an educational production function. Almost without exception (see Chizmar and Zak, 1963), the output is singular and the proxy for measurement is some type of cognitive achievement as measured through an examination. And yet, the same literature provides sound basis for a critique of the output most commonly used. The analysis provided in this dissertation recognized, through the joint product approach used, that which is generally agreed upon as common knowledge. That is, the further a student progresses through a university educational process before quitting or dropping out, the more inputs and resources that educated dropout has absorbed.

Summary

This chapter has presented the production theory which supports using attrition as an output for institutions of 'igher learning. Educated quitters then become part of a university's multi-product output. There exists a distinct difference between multiple products and joint products but the latter is considered a subset of the former type of production. A joint product production process must be considered simultaneously unless it is ascertained that the process is a factorially determined production process. The process under study here fits the factorially determined production case, the two types of which are separable and perfectly coupled. Given the inputs which include the scale of operations as defined by the number of students and the output as defined by educated finishers and educated quitters, university production fits the partially separable case; i.e., less than perfectly coupled.

Equations were presented in the chapter and the model used in this dissertation was developed. The variables used were described in enough detail to complete the model. The preponderance of variable definition along with the measurement of those variables now follows in the chapter on the description of the data.

Notes to Chapter III

1. Paul A. Samuelson points out the conditions under which a firm may have multiple products but not produce a joint product in "The Fundamental Singularity Theorem for Non-Joint Production," International Economic Review, 1966, 7, 34-41. See Also: E. Burmeister and S. J. Turnovsky, "The Degree of Joint Production," International Economic Review, 1971, 12, 99-105; and M. Hirota and K. Kuga, "On an Intrinsic Joint Production," International Economic Review, 1971, 12, 87-98.

2. H. D. Vinod, "Econometrics of Joint Production," Econometrica, April 1968, 36, 322-36, presents a discussion of joint production and then employs the econometrics which he develops in an example using mutton and wool as joint products. His efforts, though debated on certain grounds which are irrelevant to this dissertation, provided the basis for a subsequent study by John F. Chizmar and Thomas A. Zak, "Modeling Multiple Outputs in Educational Production Functions," American Economic Review, May 1983, 73, 18-22. See also: Potluri Rao, "A Note on Econometrics of Joint Production," Econometrica, October 1969, 37, 737-8.

3. See Ragnar Frisch, Theory of Production, Chicago: Rand McNally & Co., 1965, 269. Most of the theoretical parts of this chapter are extracted from Frisch Chapter 14, which may be examined for a better understanding of joint product theory. Kenneth Laitinen, A Theory of the Multiproduct Firm, New York: North-Holland Publishing Co, 1980, 5, asserts that Frisch presents a more detailed model of the firm but does so at the cost of sacrificing generality.

4. In Frisch, 1965, 269, "a" is called the degree of assortment or the degree of freedom of assortment.

5. Ibid., 270-1.

6. Chizmar and Zak, (1983) (see note 2 above), apply joint product production to education and provide yet a different example from those of Frisch. They borrow the notion of "input exhaustion" from Brown and Saks (1975), and use it to indicate the degree of jointness, or what is here referred to as degree of coupling.

7. As previously indicated in Chapter I, even those who drop out of college gain something from the educational experience. Hence, they are referred to as educated dropouts.

8. The percentage is derived as follows: (1) From Chapter II, the top 20% of the graduating high school class contributes 42% of the beginning freshmen at universities and 32% of the dropouts. (2) Of every 100 students beginning college, 40 drop out and never earn a degree. (3) 32% of 40 = 12.8 of the dropouts come from the top 20% of their high school class. (4) Because there are 42 of every 100 from that category in school and 12.8 of them drop, then nearly 31% of the nation's top high school students drop out of college.

9. The ration N_f/N_d is related to attrition (N_d/NS) by NS = N_f + N_d.

10. Had it been feasible in the elicitation process, an alternative specification like the Cobb-Douglas could have been used in lieu of the linear model used here. In the Cobb-Douglas case, the ratio $N_f/N_d = k(X_1, X_2) = X_1^{\alpha_1}X_2^{\alpha_2}/X_1^{\beta_1}X_2^{\beta_2} = X_1^{\alpha_1-\beta_1}\, X_2^{\alpha_2-\beta_2}$. The degree of homogeneity of k depends analytically on the α_i and the β_i values. See Vinod (1968).

11. See Mark Blaug, "The Productivity of Universities," in his Economics of Education, II, Baltimore: Penguin Books, Inc., 1969, 315-6.

12. See Eric A. Hanushek, "Conceptual and Empirical Issues in the Estimation of Educational Production Functions," The Journal of Human Resources, Summer 1979, XIV, 369.

CHAPTER IV

DATA DESCRIPTION AND ANALYSIS

Introduction

In this chapter, detailed descriptions of the variables used are presented along with the measurement of those variables. In some cases, assumptions are called upon in order to provide a reliable measure of specific variables. Variable definitions are provided for both data sets used in the study. The chapter continues and is further divided to provide a description of the analytical processes employed. However, the specific statistical methodology is reserved for Appendix D.

Variables Defined and Measured

The data for both the USAFA study and the UofU,MBA program were extracted from records kept at each university location.[1] Although other information was available from those records, predominant attention was placed upon the explanatory variables as already outlined in the model definition of Chapter III. Because of the differences in variables used in the two data sets, each set receives its own treatment here.

USAFA Variables

Output

While quality differences in terms of type of degree earned have been important in the literature, for various practical reasons and the fact that such differences are not great, this dissertation uses raw numbers for output. A student is classified as a finisher (N_f) if said student satisfactorily completes all of the requirements of the educational level under study such that movement to the subsequent level occurs in the next academic school year. The second output of the joint product is the number of nonfinishers (N_d). Nonfinishers are those students who begin a school year but for various reasons terminate their education at some point during the year or prior to the beginning of the subsequent year. Close scrutiny of those definitions reveals what could be a serious flaw in measurement and that is the handling of students who do not drop nor do they finish within the prescribed year but subsequently do complete.

The USAFA registrars office accounts for such students using the terminology "turnbacks into class" (TIC) and "turnbacks out of class" (TOC). A TIC is a student from a preceding class who failed to complete one or more course years of study but persisted and subsequently finished coursework with a class other than the one with which college began. A TOC student is one who did not drop from school but went back a class or more and persisted with educational pursuits. Such a TOC does not affect the attrition rate of the class with which said student started. Therefore, the entering strength of each graduating class, or each class for all four levels of education, is an adjusted entering strength comprised of new cadets or preceding level finishers plus TICs minus TOCs.

A brief example will illustrate. Assume the Class of 198x + 4 begins the freshman level of school in 198x with 1500 new cadets. During the year, 18 cadets were turned back from preceding classes. Ten members of the Class of 198x + 4 were turned back into the Class of 198x

+ 5 and 250 terminated their education at the academy for whatever reason. N_f is determined as follows:

1500 + 18 - 10 = 1508 adjusted entering strength.

$1508 - N_d = N_f$.

$250 = N_d$, so $1508 - 250 = 1258 = N_f$.

That leads naturally to the first input used with both data sets, the number of students.

Inputs

The first input is designed to determine the significance of scale on attrition.[2] Scale is measured by the number of students enrolled (NS) in raw numbers. It is defined as the adjusted entering strength of cadets into each respective class level. Using the example started in the Output section, the NS for the freshman level was 1508 students. Because $1258 = N_f$ from the freshman year, 1258 is also the NS for the subsequent sophomore year. Assume further that 200 students quit during the sophomo e year, 100 during the third, and 22 during the final year at the academy and that TICs were 3 during the third year and TOCs were 2 during the senior year. Then

$NS_1 = 1508$

$N_{d1} = 250$

$N_{f1} = NS_2 = 1258$

$N_{d2} = 200$

$N_{f2} = 1058$

$NS_3 = 1058 + 3 = 1061$

$N_{d3} = 100$

$N_{f3} = 961$

$NS_4 = 961 - 2 = 959$

N_{d4} = 22 and

N_{f4} = 937 = number graduating for Class 198x + 4.

In addition to the number of students, which is used to measure scale, four variables are used to measure quality differences in input over time. One of the four variables used to measure the differences in class characteristics is the average class score (SC) on the college entrance examination. The two most popular of such exams are the Scholastic Aptitude Test (SAT) of the College Entrance Examination Board and the exam published by the American College Testing Program (ACT).[3] The USAFA employed SAT results beginning with the first entering Class of 1959 and have continued to use SAT results to the present time. However, as more and more prospective students took the ACT, the Academy felt a need to accept ACT results. Beginning in 1974 with the Class of 1978, results of the ACT were accepted and published along with SAT results for beginning cadets.

To arrive at a common measurement, it is necessary to equate the SAT and ACT score results. Chase and Barritt provide the basis for the common relationship. The details of their effort to provide a concordance between SAT and ACT results are provided in Appendix E. The relevant range of their study as it applies to the entering USAF cadet class characteristics is shown in Table 8.

The SC used as an input variable represents a weighted average of the SAT composite mean with the average composite ACT, converted to an SAT equivalent, where the weights are based on the number of entering students taking each exam. For example, the Class of 1978 had 543 entering students take the ACT and the composite mean score was 109.4. From Table 8, 109.4 converts to 1226 in SAT terms. The same class had

Table 8[a]--Composite SAT and ACT Relationship

ACT Total	SAT Total
103.5	1167.0
104.0	1171.0
104.5	1176.0
105.0	1181.0
105.5	1186.0
106.0	1191.0
106.5	1196.5
107.0	1202.0
107.5	1207.0
108.0	1212.0
108.5	1217.0
109.0	1222.0
109.5	1227.5
110.0	123[illegible].0
110.5	1238.0
111.0	1243.0
111.5	1248.5
112.0	1254.0
112.5	1259.0
113.0	1264.0
113.5	1269.0

[a]Adapted from Chase and Barritt (1966, Table 3, pp. 107-8).

AD A147 734 A NEW APPROACH TO THE MEASUREMENT OF EDUCATIONAL OUTCOMES FOR INSTITUTIONS OF HIGH LEARNING(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH B P CHRISTENSEN 2/3

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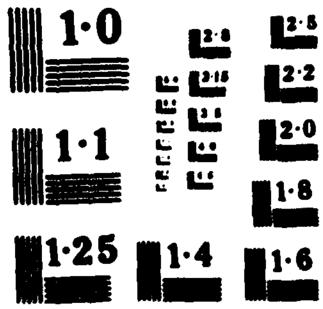
1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5

1083 entering students who qualified taking the SAT. The composite average SAT score was 1200. The weighting is approximately 2:1 for the SAT and the equivalent weighted class SC is approximately 1209.

The second class characteristic is represented by the range of scores from the SAT or SAT equivalent entrance exam. Range (RS) is used to test for the importance of homogeneity of classes entering the academy. However, a simple range; i.e., 655 (1530 - 875), is not available on a per-student basis. What is available is the low and high of the verbal and math aptitude portions of the exam for the entering group as a whole. It is obvious that the sum of the low verbal score and low math score does not represent the composite score of the lowest scoring student, just as the high scores cannot be an accurate representation of the student with the overall highest scores. The appropriate RS will always be less than or equal to the proxy measure used in this study, the sum of the lowest to the sum of the highest scores, but it is assumed that the difference will be normally distributed with some specified mean and a constant variance. Therefore, the proxy is justified. To clarify then, RS represents the range of scores from the SAT. However, it is not a simple range measure. It is a proxy measurement (or composite) where the low end of the range is calculated as the sum of the lowest scores on each of the two parts of the exam, verbal aptitude and math aptitude. The high end is the sum of the highest scores on each of the two portions of the SAT. Further work must subsequently be undertaken to test results of the simple range in college entrance exam scores and should be enlarged upon to include the range of other input variables such as the physical and leadership measures as well.

The next two class characteristics are not common inputs to a university but arise from the USAFA purpose being to prepare young men and young women cadets to become career officers in the United States Air Force.[4] These two characteristics are considered to be an integral part of the preparation, both before entering and during the four years of attendance at the Academy. One is physical (PH), the other is leadership (LD).[5]

The PH aptitude examination is a composite of performance on several athletic events and is separate from the medical examination given each cadet. It is a measure of strength, speed, agility, and general physical condition. Specifically, the cadets do push-ups, pull-ups, sit-ups, and a 300-yard shuttle run. Pull-ups are measured in terms of the number that a cadet can perform. Sit-ups and push-ups are both limited to the number completed in two minutes. The 300-yard shuttle run consists of running six round trips between two turning lines, 25 yards apart, in the shortest time possible. The runner must stay within a five-foot wide lane at all times during the run.[6] The four events are scored and each cadet awarded a score, the sum of all four events. Since this system was instituted for the Class of 1961, the mean class score has varied from 502 (Class of 1987, freshmen in 1983-4) to 573.7 (Class of 1968, freshmen in 1964-5). The lowest score ever recorded by an entering cadet was 270 from the Class of 1987 while every class has had at least one cadet score the maximum of 800 points. For this study, the class mean was used to measure the entering class candidate fitness characteristic.

The leadership composite is an attempt to measure a cadet's previous leadership experiences. The raw score is the sum of athletic and nonathletic indices. The athletic index is derived from participation and achievement in extracurricular high school athletics including baseball, basketball, football, hockey, track, tennis, lacrosse, soccer, swimming, wrestling, golf, and any other sport with which a prospective cadet may have been involved. The nonathletic index includes class or club officers, student government positions, awards in academic societies such as National Honor Society and Boy's or Girl's State Delegate, participation and achievement in public speaking, debate, drama, publications, musical activities, science clubs, scouts, Civil Air Patrol, Reserve Officer Training Corps, and membership in community and church organizations. Academy personnel feel that such athletic and nonathletic activities provide an indication of the candidate's leadership potential. "If a student has had to work to provide family financial assistance, the Academy considers the work experience as deomonstration of leadership potential in lieu of certain participation in extracurricular activities," (USAFA Preparation, 1981). The LD measure is a composite of all these leadership activities. Over the years, the range of this measure has been from a low of 970 points for one cadet in the Class of 1966 to a high of 2400 points for one cadet in the Class of 1983. The class average score was utilized here with the range of that mean varying between 1572.4 for the Class of 1963 and 1760 for the Class of 1968.

In addition to scale of operations and class characteristics, institutional inputs have an impact upon university production. One such input which has consistently been used in educational production functions is faculty quality (FQ).[7] In secondary and elementary schools, an appropriate measure of faculty quality is the college degree plus years of formal education received by each faculty member. But at a university, some other measure is more appropriate. The USAFA requires some other measure for two additional reasons. The first is the fact that all faculty members must hold at least a master's degree.[8] The second is the fact that the institution, even though accredited by the North Central Association of Colleges and Schools and the Accreditation Board for Engineering and Technology, (USAFA Catalog, 1983-4, p. 49) is operated under the auspices of the military and most faculty are Air Force officers whose selection to the faculty is based upon their experiences within the fields in which they instruct. For those reasons, faculty quality is defined as the percentage of total faculty who possess a Ph.D. or Ph.D. equivalent degree. Data for this input variable were manually extracted from The Air Force Academy Catalog which is published annually and usually precedes the beginning of the school year by several months. For example, the 1957-8 catalog was used to extract data for the school year 1957-8, even though additional faculty may have been added or some existing faculty members transferred between the time of catalog publication and actual class resumption at the beginning of the school year. Therefore, the cut-off date for measurement of FQ for a school year is the publication date of the catalog for that school year. The FQ for the USAFA ranged from a low of .1838 in 1961 to a high of .3376 in 1982.

Faculty experience (FE) is similar to FQ in that it too was taken from the catalog, so the same cut-off date for measurement applies. However, experience is not measured in the traditional sense of teaching experience. Because it is a military sponsored school and the students are professional military trainees, the FE is defined as the average number of years of military experience for the faculty as the faculty is measured from the school catalog. But even that definition requires further clarification.

Within the USAF, promotion to a specific grade is dependent upon performance of duty and time-in-grade in the rank just preceding the promotion rank. Though it is not mandatory, a great majority, say 99%, of all officer promotions follow a time-table similar to that in Table 9. The final column of that table lists the number of years of military experience used in the computation of faculty experience. A short illustration is warranted. The 1955-6 catalog shows 19 colonels, 29 lieutenant colonels, 145 majors, 181 captains, 18 first lieutenants, and 1 second lieutenant on the USAFA faculty. Using 25, 21, 14, 7, 3, and 2 as the respective military experience of each rank involved, 11.3 years is the average FE for the school year 1955-6. The FE varied from a low of 9.9 years to a high of 13.0 years for the time covered in this study.

The final institutional input used is one which is related to scale of operations but from the university side as opposed to the raw number of students. That variable is the student-faculty ratio (SF). Generally the student-faculty ratio is included in such studies to provide a proxy measure for the amount of pupil-teacher interaction. At most universities, a measure which would better describe the extent of that contact is the class size; i.e., the number of students being taught in each class offered.[9] However, at the Air Force Academy, all classrooms except eight 75-cadet and eight 40-cadet "lectinars" are built for fifteen to twenty students, thus encouraging free communication between the instructor and cadets.[10] Such being the case, little variation is manifested in the size of class being taught by each professor. Therefore, the student-faculty ratio is used, not to measure the amount of

Table 9[a]--Typical USAFA Officer Phase Points for Promotion

Rank	Year Attained	Average Service Time (Yrs)[b]	Years for Estimating FE Inputs
Second Lieutenant	0	1	2
First Lieutenant	2	3	3
Captain	4	7.5	7
Major	11	13.5	14
Lieutenant Colonel	16	19[c]	21
Colonel	22	26[d]	25

[a]This table does not reflect United States Air Force policy nor should it be interpreted as such. It is developed by the author based on personal service experience and merely presents his views of promotion within the Air Force. The predominant factor in rank advancement is NOT time but rather performance of duty.

[b]This calculated figure is based on the midpoint of time for an officer within that rank.

[c]Once the rank of lieutenant colonel (Lt Col) is achieved, an officer is generally able to elect to stay in the service even though promotion to a subsequent rank is not achieved. The average used here differs from that in the study because many Lt Cols elect to stay beyond the time when they would have been promoted to the rank of colonel.

[d]The average used here represents the average time between promotion and mandatory retirement at thirty years of service.

interaction between the two, but rather to provide a measurement of the "potential" for interaction. In that context, it is felt that a student-teacher ratio is as predictive and as important to student retention as is classroom size.

Now that the variables which are used in the USAFA study have been defined, the observations on those variable must be briefly addressed.

Observations

Establishment of the United States Air Force Academy was Congressionally authorized on 1 April 1954 and the legislation subsequently signed by President Eisenhower. The first class at the USAFA, the Class of 1959, entered preuniversity training[11] on 11 July 1955 with the formal university education beginning the fall of that same year (USAFA Catalog, 1983-4, pp. 135-7). The classes have continued since that time. The cut-off date for this study is 30 June 1983. Therefore, data covering 28 classes are available for studying the freshman model, data covering 27, 26, and 25 classes are available for sophomore, junior, and senior models respectively. And to keep the aggregate model consistent with all four levels of education, only 25 years of data are used in that model. (The years 1956, 1957, and 1958 were excluded from the aggregate model because the USAFA output was not complete during those years; i.e., there was no output from at least one level.)

However, because the first two classes, 1959 and 1960, were admitted without using a physical and leadership measure, data for those two classes had to be ignored. This posed no significant problems and the overlooking of the first two classes is similar to the accepted practice of ignoring the start-up phase in exploring the economics of a manufacturing firm. All other data were complete with no missing observations. Hence, the number of observations used throughout the study of the USAFA are 26, 25, 24, and 23 for the freshman through senior models respectively. The aggregate model contains 23 observations as well. Appendix F contains all raw data for the USAFA models along with pertinent statistical information on the observations of that data.

UofU,MBA Variables

It is essential to reemphasize that the primary purpose for including data from the UofU,MBA program is not for model building and statistical inference but rather for the descriptive value of the data itself. Nevertheless, a model is developed and the variables which are used receive their definition here to provide an understanding of precisely how they are defined and measured thus facilitating interpretation of the data.

Output

The index of output measurement used for the UofU,MBA study is measured and defined identically with that of the USAFA. That is, N_f = the number of students who finished and N_d = the number of students who drop. Ideally, this information would be available for both of the two levels in the MBA program. However, such records are not available. Therefore, the output respresents an aggregate output where N_f is the number of graduates from the program while N_d represents the number of students who started their MBA education but have never finished. They dropped out at some unknown point of time in the two-year program or at least subsequent to their entering the program.

Inputs

The first input used in the UofU,MBA modeling is the number of students (NS). It is measured in precisely the same fashion as NS for the USAFA. The second variable input, Score (SC) measures entering class characteristics just as it did in the USAFA data but the measurement is significantly different. Applicants for the UofU,MBA program are required to take the Graduate Management Achievement Test (GMAT) and submit the results to the university when making application. The results of the GMAT are then used in conjunction with undergraduate scholastic efforts in the formula

SC = (undergraduate GPA x 200) + GMAT.

The SC used for each time period in this study is the mean SC, just as with the other data set.

Range (RS) again represents the difference between the highest SC and the lowest SC for each entering class. In lieu of the PH and LD measures used for the USAFA study, the average age (AA) of each entering class is used to round out quality of class characteristics. No institutional inputs are used with this data set.

The primary reason for the change in the number of variables used with the UofU,MBA data is the shortage of observations. Adequate records for the principle two-year program begin in 1970, and data were only available to 1976. However, the input variables used provide description and measure output in two of the three general areas as do those for the USAFA; i.e., scale of operation and class characteristics. All institutional input was ommitted. The raw data for the UofU,MBA is presented later in Chapter IV.

Analyses

As previously stated in Chapter I and again in Chapter III, this dissertation employs the use of subjective or Bayesian statistical analysis. The first portion of this section provides a descriptive introduction to Bayesian econometrics beginning with probability theory and then transitioning to linear models while the later portion describes the analytical thought process which evolved as the specific statistical techniques and methods were employed.

Bayesian Statistics

The modern birth of subjective statistics occurred in 1954 with the publication of The Foundations of Statistics by Leonard J. Savage.[12] Certainly not all will be specifically referenced here, but since the publication of Savage's book, many other statisticians have written on the use of subjective statistics. Among them are DeGrott (1970), de Finetti (1972), Kyburg and Smokler (1964), Lindley (1956), Leamer (1978), Zellner (1971), and Larson (1982). All of these authors follow the initial thrust of Savage.

> The difficulty in the objectivistic position is this. In any objectivistic view, probabilities can apply fruitfully only to repetitive events, that is, to certain processes; and (depending on the view in question) it is either meaningless to talk about the probability that a given proposition is true, or this probability can be only 1 or 0, according as the proposition is in fact true or false.
>
> [Savage, 1972, p. 4]

Jeffreys (1961, p. 401) uses different words but evokes a similar meaning when he says, "No probability . . . is simply a frequency. The fundamental idea is that of a reasonable degree of belief, which satisfies certain rules of consistency and can in consequence of these rules be formally expressed by numbers . . . ." Thus Jeffreys introduces a subjective probability theory with probability being regarded as representing a degree of reasonable belief rather than a frequency.

An essential element of the subjective theory approach is Bayes' theorem. However, Leamer (1978, p. 23) points out that, "What distinquishes Bayesians from non-Bayesians is not their acceptance of the conditional probability rule but rather their willingness to apply it to events A that clearly admit no frequency interpretation." In probability notation, the Bayes theorem is expressed as

$$[22] \quad p(y,\theta) = p(y|\theta)\, p(\theta) = p(\theta|y)\, p(y)$$

and thus

$$[23] \quad p(\theta|y) = \frac{p(y|\theta)\, p(\theta)}{p(y)}$$

with $p(y) \neq 0$. This last expression can be written as

$$[24] \quad p(\theta|y) \propto p(\theta)\, p(y|\theta)$$

where $\propto$ denotes proportionality; $p(\theta|y)$ is the posterior probability density function (pdf), for the parameter vector θ, given the sample information y; $p(y|\theta)$, viewed as a function of θ, is the well-known likelihood function,[13] and $p(\theta)$ is the prior pdf. In words, then, the posterior pdf is proportional to the prior pdf times the likelihood estimator.[14]

The transition from this understanding of Bayes' theorem and the posterior pdf which follows therefrom to the application in the linear model is not very difficult. However, due to the notation involved, the specifics of the subjective posterior distribution of the linear m del are presented in Appendix D. Suffice to say here that the subjective or

Bayesian view of statistics provides a posterior estimate of the distribution on the β-coefficients. That posterior estimate has a mean which is a weighted linear convex combination of the prior mean and the maximum likelihood location with the weights being proportional to the precisions of each.

The weighted combination used in the development of the posterior estimation of β is especially useful when the data are "weak." Weak data may be a result of few observations or it may also be the result of poorly specified models. Since the USAFA has been in existence but 29 years and only 23-26 observations are available for use in this study, the role of subjective econometrics becomes even larger in providing meaningful estimates of the β-coefficients for the specified models.

Analytical Processes

This portion of the chapter is a description of the analytical thought processes which evolved as the specified statistical techniques and methods were employed. Specifically, Appendix D covers multiple linear regression and subjective statistical theory while Appendix G presents a brief yet thorough discussion of solutions to the problems which arose when the data did not conform to the assumptions which are inherent in the statistical technique employed. This section of the chapter is further subdivided according to the two sets of data, even though there are many similarities between the two sets.

USAFA

To make the USAFA data compatible[15] with the elicited prior opinions of experts, multiple linear regression (MLR) techniques were modified to force the constant value to be nonexistent and the total explanation of variation to be swallowed-up in the estimated parameter values. The model now appears specifically as

$$[25] \quad N_d = \beta_1 NS + \beta_2 SC + \beta_3 RS + \beta_4 PH + \beta_5 LD + \beta_6 FQ + \beta_7 FE + \beta_8 SF + \varepsilon,$$

with the expectation that β_1, β_3, β_7, and β_8 would have positive signs; that is, the respective independent variables have a positive effect on the number of students who drop. The number of students in a class (NS) is almost certain to have a positive influence on N_d. The statistical question becomes one of proportionality. Perhaps the cliché "misery likes company" best explains the expected positive sign on β_3 for RS. A more academically homogeneous group (interpreted by a reduction in RS) would then result in fewer dropouts because fellow classmates feel the same pressures and do not feel "alone." There is more of a feeling of identity, both with the university and with fellow students, and as indicated in Chapter II under the section on attrition, less likelihood for dropout. Less student-faculty interaction is offered as the single most critical explanation for the expected positive signs on both β_7 and β_8. In theory at least, a student is more likely to react with someone more nearly contemporary than someone else, say from the preceding generation. And the sign associated with SF presupposes that a 1:1 relation is more productive than 2:1 or 4:1.

The expected negative sign of β_2 associated with SC was debated by various authors writing on attrition. However, in the general context, a more academically prepared class, as evidenced by a higher SC, would likely have fewer students drop from the program. Each of the remaining coefficients, β_4, β_5, and β_6, could reasonably have either positive or negative signs. Adequate justification could be presented to support either sign. However, from the perspective of the USAFA, both β_4 and β_5 should be negative to justify the policy of using PH and LD as admittance criteria when faced witn increased attrition, especially if either of them is discovered to be a statistically significant determinant of attrition.

The general result of building a model like equation [25], void of the constant, is a reduction in the multiple R^2 value, that is, a small portion of the explained variation becomes unexplained while total variation remains unchanged. However, the overall result could be interpreted as a much richer description of the educational process using the inputs outlined with no additional input values tied to a nondescriptive constant value. All models were developed void of the constant value.

The next item of concern was to insure that all assumptions had been met. (See Appendix D for a list of those assumptions.) Three of the critical ones are, (1) that no exact linear relationship exists between any two or more of the independent input variables, (2) the error term has a constant variance, and (3) that the errors corresponding to different observations are not correlated. The first assumption was easy to test and the data conformed. The second was tested by plotting the squared residual values versus each of the independent variables and against time and making a visual examination to determine whether the residual term did in fact exhibit constant variation. Based on those visual observations, it was determined that heteroscedasticity was not a problem with the data and the second assumption held true.

The third of those three major assumptions did not fall so easily into place. On four of the five models developed (sophomore, junior, senior, and aggregate) the Durbin-Watson statistic indicated that serial correlation among the error terms may be a problem; at least the statistic was such that serial correlation could not be ruled out. And in three of those models (sophomore, senior, and aggregate) the form of that possible correlation was negative.

Serial correlation is a condition, usually present in time-series data, where the error term from one time period is related to an error term or terms from closely associated time periods. In the junior model under study, that association which could not be definitely ruled out was positive in nature, while in the other three models it was a negative relationship. The freshman model was the only one to effectively rule out that correlation. The negative serial correlation in the majority of the models may be explained by overcompensation in the opposite direction. That means a high dropout rate this year will be associated with a low dropout rate next year. (This presupposes that a university has a great deal of control over who drops and who stays.) This process continues but obviously within certain bounds.

Pindyck and Rubinfeld (1981, p. 153) commenting on serial correlation, say: "As a general rule, the presence of serial correlation will not affect the unbiasedness or consistency of the ordinary least-squares regression estimators, but it does affect their efficiency." Therefore, the Hildreth-Lu procedure (see Appendix G) was implemented to atone for the loss of efficiency. The models so corrected take the form found in equation [26].

$$[26] \quad (Y_t - \rho Y_{t-1}) = \beta_1(X_{1t} - \rho X_{1t-1}) + \beta_2(X_{2t} - \rho X_{2t-1}) + \dots (e_t - \rho e_{t-1}).$$

The models requiring correction (sophomore, junior, senior, and aggregate) now appear as

$$[27] \quad (N_{d_t} - \rho N_{d_{t-1}}) = \beta_1(NS_t - \rho NS_{t-1}) + \beta_2(SC_t - \rho SC_{t-1}) + \beta_3(RS_t - \rho RS_{t-1}) + \beta_4(PH_t - \rho PH_{t-1}) + \beta_5(LD_t - \rho LD_{t-1}) + \beta_6(FQ_t - \rho FQ_{t-1}) + \beta_7(FE_t - \rho FE_{t-1}) + \beta_8(SF_t - \rho SF_{t-1}) + (\varepsilon_t - \rho\varepsilon_{t-1}).$$

The classical results, after correcting for correlation where necessary, are presented in raw form at the beginning of Appendix H.

Following the development of the classical models as indicated by equation [27], the attempt was made to develop a more explicit classical model of the major determinants of attrition through the use of stepwise regression. "In stepwise regression one adds variables to a model to maximize R^2 or equivalently to minimize the error sum of squares (ESS)," (Pindyck and Rubinfeld, 1981, p. 93). However, the results of such a stepwise regression have to be carefully interpreted.

> While stepwise regression can be useful in helping one to look at data when there are a large number of possible explanatory variables to include, it is of little or no value when one is attempting to analyze a model statistically. The reason is that t and F tests consider the test of a null hypothesis under the assumption that the model is given correctly, i.e., correctly specified. If we have searched over a large set of variables, selecting those that fit well, we are likely to get significant t tests with great frequency. As a result, the large t statistics do not allow us to reject the null hypothesis at a given level of significance.
> [Pindyck and Rubinfeld, 1981, pp. 93-4]

The classical results of the stepwise regression are included as part of Appendix H.

After all classical results were obtained, the elicited opinions of three individuals closely associated with the admissions process at the academy were averaged.[16] The averages were used with the MLE results in the previously specified weighted fashion to obtain the posterior distribution of the β_i. That posterior distribution of the β values is a t-distribution with the location specified by the posterior β values found in the last section of Appendix H. It is precisely that posterior distribution upon which many of the conclusions of Chapter V are based.

UofU,MBA

The UofU,MBA model is explicitly given as

$$[28] \quad N_d = \alpha_1 NS + \alpha_2 SC + \alpha_3 RS + \alpha_4 AA + \mu.$$

The raw data are presented in Table 10.

Chapter Summary

Chapter IV has been a presentation of the input and output variables used in this dissertation. Definitions were provided and measurements of the variables described. The chapter concluded with a section on the analyses which were performed. A major portion of that section was devoted to a description of Bayesian (subjective) statistics and the role that Bayes' theorem plays in arriving at a posterior pdf, or in the

Table 10[a]--Raw Data for UofU,MBA Program

Year	N_d	NS	SC	RS	AA
1970	52	98	1079.234	499	26.557
1971	49	78	1099.577	462	26.654
1972	63	85	1090.877	639	27.357
1973	36	75	1110.227	597	26.160
1974	43	77	1113.581	473	26.416
1975	40	78	1131.513	449	26.115
1976	31	65	1162.609	511	26.344

[a]Data were extracted from University of Utah records by personnel associated with the MBA staff. It was provided this author in raw form on an individual student basis and was further condensed to represent class data as it appears here.

case of the linear model, the posterior distribution of the β-coefficients. A word of caution is paramount at this point, and that is--the posterior β_i are not meant to be observable characteristics which describe the real world. Instead, they represent the author's opinions about the observable and measurable inputs and outputs of the particular university under study. Therefore, great care must be exercised in drawing conclusions and the inference which those conclusions have for other institutions as regards to attrition from universities.

Notes to Chapter IV

1. The USAFA Office of Research (RRE) made available all information of a data nature. Most was extracted from United States Air Force Academy, Statistical Summaries of USAFA Cadets and Graduates, Colorado Springs: USAFA/RRE, June 30, 1983. Other pieces not available in that publication were taken from data maintained by RRE on the characteristics of entering classes at the Air Force Academy. Data for the UofU,MBA program were collected by personnel associated with that program and taken from school records and personal student files.

2. Although not performed specifically for the effect upon attrition, Lawrence W. Kenny, "A Model of Optimal Plant Size With An Application to the Demand for Cognitive Achievement and for School Size," Economic Inquiry, April 1982, XX, 250, found that the scale of operations as defined by school size is an important factor in measurement of student achievement. For that reason, scale becomes a question of interest in examining attrition at universities. See also: P. A. Watt, "Economies of Scale in Schools: Some Evidence from the Private Sector," Applied Economics, 1980, 12, 235.

3. See Clinton I. Chase and L. Spencer Barritt, "A Table of Concordance Between ACT and SAT," The Journal of College Student Personnel, March 1966, 7, 105; and Oscar T. Lenning, Predictive Validity of The ACT Tests at Selective Colleges, ACT Research Report No. 69, Iowa City: ACT Publications, 1975, 1. The latter work also contains the results of a case study comparing results of entering students who took the SAT with those who took the ACT at the USAFA during the 1967 - 1969 freshmen years. The conclusion of that case study was that the ACT is as predictive as the SAT for predicting student success at a selective university. See pages 5-10 of that report.

4. See The United States Air Force Academy--Questions and Answers, 1983, 1.

5. See "Preparation," 1981, a pamphlet prepared by the USAFA and sent to all potential enrollees of the Academy. Physical refers to the strenuous body-building activities while leadership takes in a host of areas such as high school student government, scouts, and membership in community organizations.

6. See The United States Air Force Academy Catalog, Colorado Springs: Admissions Liason Office, 1983-4, 93. The yearly published catalog contains information on all requirements for admittance to the Academy.

7. See the educational production function studies which were referenced and reviewed in detail in Chapter II and Appendix C.

8. See The United States Air Force Academy--Questions and Answers, 1983, 22. Also see all editions (1956 - 1984) of the institutional catalog which lists individual faculty members along with their respective scholarly accolades.

9. Steven T. Bossert, Chairman of the Educational Administration Department at the University of Utah, feels that the student-faculty ratio is a poor measure of that interaction. In an oral interview with the author, he expressed that perhaps a better measure of pupil-instructor contact would be class size as defined by the number of students in each class being taught.

10. See Catalog, (1983-4), 50; also Questions and Answers, 1983, 20.

11. This preuniversity training is military in nature. All prospective cadets go through this training which might well be likened to basic military training which all service inductees receive. Even though there is considerable attrition from this part of the cadets' program, this effort only focuses upon attrition from the univeristy subsequent to the Basic Cadet Training (BCT) as it is called.

12. The first alternative to the objective view that probability is a physical concept such as frequency, was enunciated by James Bernoulli, 1713, in Ars Conjectandi. He said that probability is a "degree of confidence." Savage made the first publication of his work Foundations in 1954. Subsequent to that time he reevaluated his position somewhat and reconsidered the appropriateness of many frequentistic applications. The second edition was then published in 1972, not appreciably changing his first publication, but adding more recent developments, a new preface, new footnotes, and a supplementary 180-item, annotated bibliography. Savage asserts that "the foundations are the most controversial a subject as one could name." (Savage, 1972, 1)

13. Usually the likelihood function is expressed as $\ell(\theta \mid y)$ to emphasize that it is not a probability density function (pdf), whereas $p(y|\theta)$ is a pdf for the sample observations y given the parameters θ.

14. For a treatment of this extremely critical facet of Bayesian econometrics, see Arnold Zellner, An Introduction to Bayesian Inference in Econometrics, New York: John Wiley & Sons, Inc., 1971, 13-57; or Edward E. Leamer, Specification Searches, Ad Hoc Inference with Non-experimental Data, New York: John Wiley & Sons, Inc., 1978, 22-40.

15. Compatability referred to here is for matrix algebra purposes.

16. Several methods currently exist for reconciling the differences between elicited opinions of two or more experts. One such method is "Delphi," a technique developed for the military by Rand Corporation. See Dalkey and Helmer (1963), Gordon and Helmer (1966), Gordon (1968), Dalkey (1968), and Linstone and Turoff (1975). Another form or alternative, also developed by Rand is "Delphi Method II." See Brown et al., (1969). Both of these methods were created to ameliorate difficulties associated with face-to-face task groups. Delphi is a forecasting method which makes use of subjective probability theory and which is designed to depersonalize or reduce personal sources of bias in preparing forecasts. It provides a system for combining expert opinions into a group consensus of probabilistic events. Much has been written,

both pro and con, on the Delphi Method. See Sahal and Yee (1975), Nelson (1975), Spangler (1976) and Bunn (1979). Due to some of the problems inherent in Delphi, Ford (1975) developed an alternative to Delphi called "Shang Inquiry" and Brockhaus (1975) developed POSTURE, a Policy Specification Technique Using Realistic Environments. Perhaps the most critical approach to Delphi, however, comes from Morris (1971, p. 6) where he writes, "...the most succinct way to characterize Delphi from our point of view is as a classical statistics treatment of an inherently Bayesian problem." Most of the techniques mentioned are primarily concerned with the opinions of experts in forecasting for policy formulation or taking some action based on those opinions. Because this dissertation utilizes the subjective opinions in a weighted fashion with maximum likelihood estimators in an attempt to explain rather than forecast, a simple average of the three elicited opinions is used in this study in lieu of Delphi or any other group consensus technique.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This final chapter contains the results and conclusions of the study on the two data sets. In all cases, results are presented in table form (either in this chapter or in Appendix H) for all levels of the study for which specific models were developed. However, following the macro approach which was previously specified in Chapters I and III, and for which a university shows major concern regarding attrition, the emphasis is on the conclusions for the aggregate model even though individual models are discussed. During any given academic year, the undergraduate university has students enrolled in all four levels and attrition can occur from any one of those four. Hence the interest for policy planning should be focused on the determinants of attrition from all four levels simultaneously--the aggregate model. In presenting the conclusions, specifics are offered and the care spoken of in Chapter IV is exercised as implications are drawn for both the classical and subjective statistical results. Additionally, recommendations are given. These fall under one of two categories, recommendations based on the findings described herein and recommendations for further study in the area of attrition from universities, the latter having its own section. The chapter is drawn to a close with a study and chapter summary.

General

The result of applying joint product production theory to institutional output for universities is most interesting. It is strongly believed that the results are sufficiently positive to suggest that the same method be put forth as a possible way of researching all output of a university, including research and community service. Perhaps such efforts could use the tri-level output measures themselves as the joint output with various combinations of inputs, following the examples of Chizmar and Zak (1983). But, what is it that allows one to conclude positive results? It is imperative that that question be answered within the realm of the classical and subjective statistical results respectively.

Classical Results

One of the most striking results of the maximum likelihood estimator equations is the value of the adjusted R^2 for each model. (R^2 is defined as the percentage of variation "explained" by the linear relationship depicted in the model developed.) When estimating the number of students who will drop out, the adjusted R^2 took on values of .92 for freshmen, .90 for sophomores, .56 for juniors, .44 for seniors, and .89 when calculated on the aggregate. When the estimation is accomplished for the number of students who finish as expressed by equation [16], the alternative equation for the joint product output, the relationship exposed in [17'] is numerically derived (see Chapter III) but the adjusted R^2 is significantly different from that associated with the respective N_d equation. The adjusted R^2 values for each N_f model are presented in Appendix H along with the statistical information for the estimated N_d models. R^2 values for N_f were .992, .995, .990, .998, and

.996 for the freshman through aggregate models respectively.

All of these R^2 values are for models which are "good fit models," statistically speaking. The degree of statistical significance is determined by the F statistic which is presented as a part of the classical results in the tables of Appendix H. The F statistic can be used to test the significance of the R^2 value. In all models, the F value was large enough to conclude that R^2 was definitely greater than zero. Strictly speaking, the F statistic is a summary test of the hypothesis that none of the independent variables helps to explain the variation of the dependent variable about its mean. In other words, the F statistic tests the joint, null hypothesis that $\beta_1 = \beta_2 = . . . \beta_8 = 0$. If the null hypothesis is true, one would expect R^2, and therefore F, to be close to zero. The relatively high values of R^2 and F for the developed models provide rationale for rejecting the null hypothesis and concluding statistically significant models with one or more β_i different from zero. A discussion on which specific inputs are statistically different from zero is reserved for the next section. However, the signs of the coefficients (positive or negative) are an important part of the classical model results.

There was not a single input variable which maintained a consistently positive or negative sign throughout all five models. All signs from each of the models are presented in Table 11. As equation [17'] showed earlier, all of the N_f coefficient signs, except that associated with NS, are reversed; i.e., if the sign is negative in Table 11, it is positive for the N_f equation; but of identical magnitude. In examining the coefficient signs and making a comparison with the expected signs as expressed in Chapter IV, it is essential to proceed in a

Table 11--USAFA Models' Signs of N_d Coefficients

	Model[a]				
Variable	Freshman	Sophomore	Junior	Senior	Aggregate
NS	(+)[-]	(+)[+]	(+)[+]	(-)[+]	(+)[+]
SC	(-)[-]	(-)[-]	(+)[+]	(+)[+]	(+)[-]
RS	(-)[+]	(-)[+]	(-)[-]	(+)[-]	(-)[+]
PH	(-)[-]	(+)[-]	(-)[+]	(-)[+]	(-)[-]
LD	(+)[-]	(-)[+]	(+)[-]	(-)[-]	(-)[+]
FQ	(-)[0]	(-)[0]	(+)[0]	(+)[0]	(-)[0]
FE	(+)[-]	(+)[+]	(-)[-]	(-)[-]	(+)[+]
SF	(+)[0]	(+)[0]	(-)[0]	(-)[0]	(+)[0]

[a]For ease of interpretation, the MLE sign is included in (parentheses) and the prior opinions sign is in [brackets]. The signs on the subjective posterior coefficients depend on the weighting (τ_0) used. See Tables 31 and 32 in Appendix H.

coefficient by coefficient manner in conjunction with the magnitude (how large in a positive or negative direction) of each coefficient. Such a step by step comparison follows in the Subjective section.

Subjective Results

An astute observer of the traditional numerical results alone may conclude that only one or two input coefficients are statistically different from zero. However, such a statement implies some standard level of statistical significance--usually 5 percent. Subjective econometrics takes an altogether different view of the hypothesis testing routine.[1] Basically, all coefficients become statistically significant at some level of willingness to accept the fact that the null hypothesis was incorrectly rejected. (See Appendix I for an indepth explanation of Type I and Type II errors along with a definition and explanation of the power function.) But in accepting the fact that the null hypothesis was incorrectly rejected, the power of the test is increased.

If the researcher did not have strong a priori thoughts or opinions about the variables included in his model, he would not include them.

> It is neither surprising nor unwarranted that a large informative sample leads to the rejection of the hypothesis. One, in those circumstances, should trouble himself not with the results of classical hypothesis testing but rather with the question of why he bothered to test a false hypothesis in the first place. As it turns out, hypothesis testing does have some validity, even when a restriction is practically certain to be false. . . . we are thus concerned with situations in which classical hypothesis testing has an unambiguously legitimate function.
>
> [Leamer, 1978, pp. 89-90]

Model specification is itself, then, often subjective by nature. More specifically the coefficient values themselves are declared statistically significant based on a subjective willingness to accept a larger

Type I error. With that brief introduction to the importance of subjectivity, implicit in classical analysis, the step by step review of coefficient values and signs can be accomplished.

The coefficient sign attendant NS appeared positive, as expected, in four of the five models. The fifth model was for the senior year. It is of importance to note that the senior NS coefficient is the only one associated with NS which does not appear statistically significant, even to the $\alpha = .40$ level. All other NS coefficients were significant at the $\alpha = .05$ level. (The conclusions, as they apply to all inputs, for university policy implementation are reserved until later in the chapter.)

The sign of the SC coefficient was not as consistent as that of NS nor was it consistent with the expected negative sign. It only appeared negative in the freshman and sophomore models but neither of those two coefficients was statistically significant at any level to $\alpha = .40$. All three positive signs appeared with coefficient values which were statistically significant to some specified level. The interpretation of the positive sign is that an increase of 1000 points in class SC will result in a significant (217-298) increase in N_d, or equivalently, approximately 20-30% of the increase in SC; i.e., if SC increases by ten points while all other inputs are held constant, two or three more students will drop from that class with the ten points higher SC, sometime during the junior or senior year.

RS produced coefficients which were more frequently opposite in sign to that expected. Four of the five were negative with three of those four being significantly different from zero. The senior model had a significantly positive sign while the freshman model appeared insignificantly negative. In words, an increase in RS should theoretically result in a decrease in N_d, by approximately 13-28% of the RS increase.

As previously indicated, PH, LD, and FQ coefficient signs could justifiably be expected to be either positive or negative. In the case of PH, four of the five parameter values were negative with three of them being *statistically significant* at α = .40. The junior model parameter was the negative, insignificant one while the sophomore model produced a positive but insignificant coefficient. Neither LD nor FQ exhibited much in the way of statistical contribution to the model. However, the FQ coefficient was significantly negative in both the sophomore and aggregate models with a specified α = .20. As for the FQ contribution to the model, a one percent increase in FQ should result in a decrease of 3-4 persons in the N_d dependent variable.

Both FE and SF coefficients were expected to have positive signs, and in three of the five models, both had positive signs. The negative parameter values occurred in the junior and senior models for both variables. The most notable difference between the two variables is the consistent statistical importance of FE and the lack of such consistency in SF. The significance of the FE coefficient creates a situation which could be termed paradoxical. That is, an icnrease in FE by one year will, in theory at least, result in increased N_d by 14-23 students during the freshman and sophomore years. However, that same increase in FE results in a decreased N_d of 7-16 students during the junior and senior years. The inferences for USAFA policy of such a paradoxical situation are reserved for the subsequent section on USAFA Conclusions. The SF coefficient was found to be significant at α = .20 in the sophomore model and at α = .40 in the aggregate model. An increase of the SF ratio by one, i.e., from 10:1 to 11:1, will theoretically result in an increase of 2-6 N_d students.

All subjective posterior coefficient estimates are in agreement with the preceding paragraphs on the subjective interpretation of classical results. (See Table 31 in Appendix H for posterior parameter estimates.)

The major hypothesis tested in this dissertation was stated as being an empirical test of the joint product methodology put forth. Although no comparison was made between the joint product output as defined herein and a single output equation, the results of the joint models are statistically positive enough to conclude sound methodology. A comparison is not required directly. The literature reviewed in Chapter II showed that a university's output is multi-product. The major hypothesis here was that a joint product production function would satisfactorily measure the joint products. The results are sufficiently meaningful in that every model developed proved to have variables in each of the three specific areas studied, scale of operations, student characteristics, and university or institutional characteristics which were statistically significant contributors to the model development.

Conclusions other than the major one already stated are for the specific data sets and are covered under their respective areas which follow here.

USAFA Conclusions

In every one of the five models developed and particularly in the aggregate model, NS, representing the scale of operations for the Air Force Academy, was found to be statistically significant. (See Table

12.) Thus from the standpoint of policy with respect to current enrollment levels, the number of students enrolled is of statistical importance in its effect upon the number of studnents who drop. In an effort to determine the extent and direction of that significance, a classical regression representing a cubical parabola was accomplished.[2] A general graphic presentation of the USAFA models, using the cubical parabolic form is presented in Figure 9. The data reflect that there exists some local minimum and maximum N_d for a specified NS level. To precisely locate NS where the local minimum and maximum occur, the first partial derivative of the N_d cubical equation was calculated with respect to NS. The results, after checking to confirm whether each root was a minimum or maximum, for each model are presented as part of Table 13.

When compared to the actual number of students who have historically been admitted to the Academy (the last row of Table 13), the initial conclusion is that the scale of operations, with regard to the

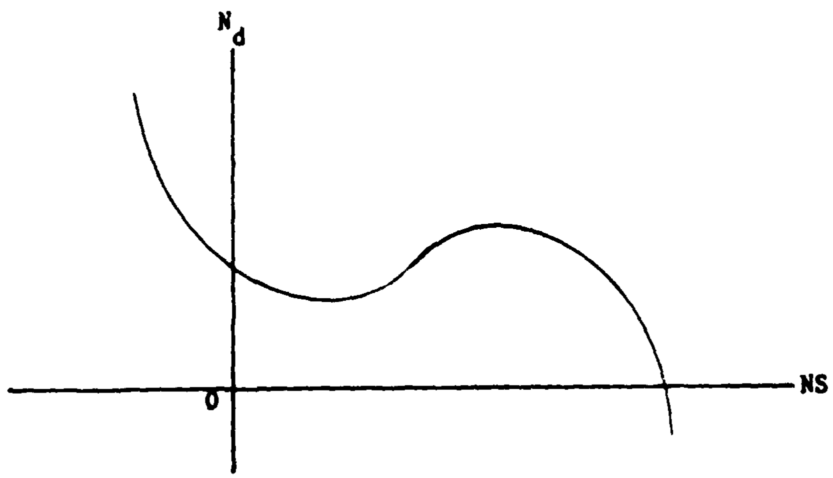

Figure 9. Typical Cubical Parabola for USAFA Data

Table 12--Statistical Significance of USAFA Coefficients

Variable	Freshman	Sophomore	Junior	Senior	Aggregate
NS	.95	.95	.95	.95[a]	.95
SC			.60	.95	.60
RS		.60	.95	.60	.90
PH	.60			.60	.60
LD	.60				
FQ	.60	.80			.80
FE	.95	.90	.80	.80	
SF		.80		.60	

[a]This significance is for the N_f equation.

Table 13--NS Values Where N_d is at a Local Minimum or Maximum

NS[a]	Freshman	Sophomore	Junior	Senior	Aggregate
Minimum	.37	.33	.39	.27	2.67
Maximum	1.44	-3.41	.93	.67	6.18
Historical Average	1.116	.909	.792	.718	3.697

[a]NS is presented in thousands.

number of cadets, has been excessively large, i.e., NS was at a point where the resulting N_d was greater than the local minimum. Thus NS was, in effect, contributing to attrition. Table 13 also indicates that when the total Academy (aggregate) NS reaches 6180, the local maximum N_d will be reached and as NS grows beyond that point, N_d would theoretically start a decline. Caution must be exercised, however, because that scale of operations in the cubical equation has never been experienced and thus lies outside the parameters for safe extrapolation.

The key to the overall effect of scale on attrition is in the explicit academy goal (as previously established in Chapter I) to produce 1000 graduates. The cubical model for seniors indicates that N_d for seniors will be extremely low when 1000 or more cadets begin the senior year. Of course, students have to complete the first three years to enter the fourth, but once the attrition rates are theoretically known for seniors, each respective prior level model can in turn be developed and ultimately the optimum scale of operations derived for the initial freshman entering class. When used in conjunction with the academy goals in that fashion, it is concluded that the scale of operations is too small, both for attrition and for the goal.

Of the four class characteristics measured, the most important discovery dealt with the range of scores from the college entrance examination for each class entering the institution (RS). The importance of that variable input is in the sign attached to the coefficient. As shown in Table 11, in all of the models developed except the senior model, the RS coefficient took on a negative (-) sign in the drop (N_d) equation. That means if the academy admissions policy allows increases in the range of score for any given entering class over the RS for another class with comparable characteristics, the class with the greater range is less likely to have a greater number of students quit at every step along the four year university ladder to an undergraduate degree. In other words, the more heterogeneous (as measured by a larger RS) a given class is as it enters school, the more likely it is to have a higher percentage of the entering class complete. The negative sign is contrary to the expected positive sign as previously expressed in Chapter IV. Therefore, it is acknowledged that the exposed effect of RS on N_d is counterintuitive.

Given that heterogeneity quality, it then becomes critical to examine the effect of the magnitude of coefficient values of the remainder of class-characteristic variables in conjunction with the signs attached to the respective coefficients. Of the remaining three class-characteristic variables, the most significant was score (SC). The positive (+) sign attached to the aggregate level coefficient of the N_d equation, theoretically indicates that if the overall entering class SC were increased, the number of students who quit the academy would also increase. Of course, this result is contrary to reason, to the expected sign of the coefficient attached to SC, and to the desires of a university to admit better academically prepared classes. However, it does provide some evidence in support of the finding of Iffert (1958) that 30.5% of those in the top fifth of their high school class and who go on to college, drop. (See Appendix B for a review of the Iffert study.) This finding also agrees with Cope and Hannah (1975, pp. 104-5) where they stress other factors besides high SAT or ACT scores for college admission. In addition, the negative coefficients on the freshman and sophomore models theoretically indicate that a decrease in SC will result in increased N_d during those two years and fewer N_d in the junior and senior years. This has the effect of having dropouts occur earlier in the program and thus keeping cost per dropout lower than if they drop as juniors or seniors.

Thus, entrance exam scores, as measured by the entering class average SAT or SAT-equivalent score, can be predictive, not of the individual's dropout behavior but of the overall class dropout behavior. However, the most important aspect of SC comes when its conclusions are combined with those of RS previously described. The results of the USAFA data study indicate that a class which enters school with a lower class mean on the college entrance exams and which is not quite so closely grouped, or more heterogeneous, as measured by the range of scores on the same examination, will likely lose fewer students to attrition.

The other two class-characteristic variables lag somewhat behind RS and SC for explanatory power. The physical (PH) measure provides predominantly the same results as those just described for SC in the freshman model. An increase in the class level of achievement in PH is most likely to result in a decrease in the number of students who fall by the wayside and drop out of the academy during the freshman, junior, and senior years. The sophomore year is an exception but is insignificant. However, the leadership (LD) variable, with a positive (+) sign attached to the freshman model coefficient, is theoretically interpreted that an increase in the class average LD score will result in an increase in the number of dropouts from that class in the freshman year. Temper that with the fact that all other LD MLE coefficients are not statistically different from zero and two of the three elicited expert opinions specified that LD as an input has no effect upon the number of students who will finish. Certainly from a policy point of view, LD implicitly appears as one of the least significant of the class characteristic input variables in the aggregate model.

Of the three variables representing the institutional inputs of the educational production functions, faculty quality, faculty experience, and student-faculty ratio, Table 12 and the stepwise regression procedure both indicate that faculty experience is the one having the most effect upon retention of students in the academy environment. When looking at the freshman, sophomore and aggregate models, fewer students are likely to drop from school during the years when faculty experience is lowest. Because the measurement of the FE variable was defined as "years of military experience," the interpretation of the signs (Table 11) on the coefficient attached to FE is that freshman and sophomore students relate better to more contemporary junior officers. As the experience level of the faculty at the USAFA increases, the numbers of freshmen and sophomores who drop will increase also. This is a meaningful argument for a policy of using military professors with less military experience, and/or a more collegiate orientation in the lower division courses most likely taken by freshmen and sophomores. However, lowering FE has the effect of increasing N_d among juniors and seniors, so the same policy paradox occurs when treating FE as already discussed in SC. By increasing FE, more freshmen and sophomores but fewer juniors and seniors will drop. The cost per dropout may be reduced by having more cadets drop during the early years and fewer during the latter.

The last variable input measured, student-faculty ratio (SF), did not emerge as a very important factor. As Table 11 shows, an increase in the SF may be detrimental to retention rates, particularly in the early years where the most significant SF coefficient occurs for the sophomore model. The aggregate model, though not as statistically significant, supports the conclusion. The negative signs which do appear are not of statistical importance. Therefore, smaller student-faculty ratios are likely to result in decreases in the number of students who drop.

Based on all of these findings, *it is concluded* that the joint product educational production function is a valid method for measuring output at the USAFA, particularly as that output applies to educated graduates and educated nongraduates. The models indicate that the most profitable areas for change in attrition are the scale of operations, faculty experience, and two of the class characteristics, SC and RS. An increase in scale of more heterogeneous students with a corresponding increase in faculty, i.e., SF ratio constant or declining slightly, could theoretically result in reducing attrition and subsequently reducing the cost per graduate at the USAFA. More heterogeneous inputs should be encouraged and where possible, the more diverse group of students should be evidenced by greater spread at the lower end of the spectrum whether that be for college entrance exam scores, a physical conditioning measure, or any other measure used for student admittance criterion. It is reemphasized here that such institutional changes will not insure the completion and graduation by a given student but the overall completion rate can be improved.

UofU,MBA Conclusions

It was previously stated that the data for the UofU,MBA program would be presented primarily for descriptive purposes. The primary reason is the obvious lack of data. Table 10 in Chapter IV presented the data. Table 14 is a presentation of the results of performing the aforementioned statistical routines. The results which are most obvious are the relatively high R^2 value with its attendant F-value, a statistically significant negative coefficient with score (SC), and the extremely important part which the average age (AA) plays in helping to explain the variation of the number of students who drop. Contrary to the USAFA results, the scale of oeprations does not have a significant effect.

Of the two significant inputs, AA appears more important. It appears that a younger class will have a better opportunity to complete a higher percentage of the enrolled students. One possible explanation is that older students (if they could be specifically identified as the dropouts) may enroll in the two-year MBA course of study only to improve

Table 14--UofU,MBA Results (N_d)

Variables	MLE Coefficient (SE)	Prior Opinion	Posterior Coefficient (τ_o = .01)
NS	-.0689 (.274)	-.0003	-.0682
SC	-.2633 (.071)	-.0600	-.2613
RS	-.0165 (.029)	.0569	-.0157
AA	13.2704 (3.961)	3.4250	13.173
R^2	.924		
SEE	4.196		
F-value	12.155		
Durbin-Watson	2.626		

their knowledge of business and not with the express goal of graduation, whereas, the younger students right out of undergraduate school may be attempting to improve job opportunities and are thus more intent on completing the coursework.

SC is also a significant factor, and the negative sign is more in consonance with the sign one would expect on SC. That is, the sign indicates that an increase in the class average score, as previously defined in Chapter IV, will theoretically result in fewer students quitting. The difference between the two data sets for this coefficient sign could logically be explained by the hypothetical belief that academic achievement as measured by the respective SC is more important to a graduate program than to an undergraduate one.

Based on these results, which are in turn based on few data points, the University of Utah MBA school can theoretically reduce the number of students quitting the program by seeking to have younger, more academically prepared students enter the two-year program.

Recommendations for Further Research

The recommendations for further research which have evolved from the results of the data study of this dissertation and from questions encountered during the research phase, basically fit into four categories. The first two are general in nature and could logically be studied at any university or college. The third area applies to the study of universities which fit into a certain category--those which screen candidates and recruit students. The final area applies to service academies in general and the United States Air Force Academy specifically.

The results of the two data sets are sufficient to warrant further testing and application of the joint product *educational production functions* for colleges and universities. It is recommended that such testing, paralleling that used herein, be accomplished at a larger, state operated university. It is also recommended that future studies explore the feasibility of using other indices of output measurement, including those previously mentioned: credit hours completed, grade-point-average, a combination such as credit hours times grade-point-average, or number of students (finishing vs. dropping) times grade-point-average times credit hours. Any one of these measures appears warranted because of the emphasis placed upon them by the colleges and universities in the United States as well as that placed by potential employers as they examine college records of applicants. Such studies performed should provide valuable information to any university which is concerned with reducing attrition.

A further recommendation applies to any university which can afford the luxury of recruiting or screening applicants for admission. Explicit cost functions need to be developed for the recruiting/screening process in such a fashion that the magnitude of resources saved through enlarging the recruiting process can be readily determined. This will result in admitting students with more desirable class characteristics, thus reducing attrition and ultimately the cost to the school, the student, and other parties actively involved with the higher educational process. The time, if not already here, is rapidly approaching when many applicants, even though highly desirous, will not be afforded college educational opportunities due to the lack of secondary school preparation. Increasing the scope of the recruiting/screening process can be most profitable under such circumstances.

Personnel at the USAFA should closely examine the political processes involved in admitting students to the Academy. As it was emphasized in Chapter II, many different student characteristics are measurable and yet historical studies provide no basis for determining whether or not a specific student, given certain characteristics, will persist to graduation. Therefore, admission processes must be such that those applicants who contribute most to the critcal class characteristics which are indicative of a lower attrition rate be given every opportunity to attend the USAFA.

Study Summary

This dissertation examined attrition at universities using a joint product educational production function. Data sets from two sources were examined using subjective statistical analysis techniques in an attempt to discover the validity of the joint product methodology as well as highlighting which if any of the input variables used were critical in light of attrition rates at universities. The United States Air Force Academy was used as a primary source of data. The variables employed were grouped so as to measure the scale of operations, input characteristics of the particular group of students attending the university, and technology of the institution itself. All inputs were macro in that the emphasis was not on a given student, but rather on the group to which the student belonged.

Chapter II presented a detailed review of the literature and the work which has been accomplished on attrition and on the use of educational production functions. This effort, in effect, merges the two portions of literature. Chapter III presented a step by step development of the theory of joint product. And, because the joint output was selected to be educated finishers and educated dropouts with the total number of entering students as an input, the explicit joint product functions became single with the implicit joint product function not being directly estimated in this dissertation. Chapter III also outlined the specific methods employed while Chapter IV described the data from the United States Air Force Academy and the University of Utah, two-year Master of Business Administration program. A unique feature of Chapter IV is in the analyses where subjective, Bayesian econometrics is applied for the first time to educational production functions. One interesting facet of that technique is the process called elicitation which is further developed in Appendix A. This chapter has been a presentation of the conclusions reached as a result of the two separate data sets studied. Increasing the number of entering students, particularly in such a fashion that a more heterogeneous class of students is enrolled, the data indicate that numbers of educated dropouts can be significantly reduced as a proportion of those attending the academy. In addition, an increase in faculty experience, though having an adverse effect upon freshman and sophomores, could be a cost-per-dropout-savings factor in that fewer juniors and seniors would quit.

The UofU,MBA data revealed that age has a positive effect on the number of students who drop from that graduate program. And, the level of academic achievement appears to be more significant for graduate program retention than for undergraduate programs.

The overall results were sufficiently positive to indicate that attrition can be successfully examined using joint product production functions and it is recommended that major follow-on studies be undertaken.

Notes to Chapter V

1. In Edward E. Leamer, Specification Searches, New York: John Wiley & Sons, 1978, 87-131, a comprehensive view of the subjective approach to hypothesis testing is presented. Some of his work is also included in Appendix I. See Pindyck and Rubinfeld (1981, pp. 26-40) for a synopsis of the traditional views on this subject.

2. A cubical parabola is of the form $Y = aX^3 + bX^2 + cX + d$. For the purposes of this dissertation, $N_d = aNS^3 + bNS^2 + cNS + d + \beta_2 SC + \beta_3 RS + \beta_4 PH + \beta_5 LD + \beta_6 FQ + \beta_7 FE + \beta_8 SF$. All elements to the right of cNS are considered part of the intercept. To pinpoint precisely the location of the intercept, the mean value of sample inputs can be used in conjunction with the respective coefficient and summed over all elements contributing to the intercept value. The resultant cubical parabola, descriptive over the relevant range of the academy history, theoretically provides information on the effect of scale on the number of students who drop (N_d).

APPENDIX A

ON ELICITATION[1]

One formal way of developing prior opinions about the parameters (coefficients) of a model is to ask someone who is in the know about such affairs as are under study. These are the 'experts' referred to in the text. But when dealing with multiple coefficients such as the case of multiple regression models, it is extremely difficult for an expert to express opinions directly about each coefficient. This is even more of a problem when the information desired is about the distribution of those coefficients. The way around this difficulty lies in the following mathematical relationships:

$$[29] \quad E(Y|X_1, X_2, \ldots) = X_1E\beta_1 + X_2E\beta_2 + \ldots,$$

$$[30] \quad V(Y|X_1, X_2, X_3, \ldots) = X^2{}_1V\beta_1 + X^2{}_2V\beta_2 + X^2{}_3V\beta_3 + \ldots + 2X_1X_2C(\beta_1\beta_2) + 2X_1X_3C(\beta_1\beta_3) + 2X_2X_3(\beta_2\beta_3) + \ldots + \sigma_e^2,$$

where: E = expected value (elicited value in the case of Y)

β_i = coefficients,

V = variance,

C = covariance,

X_i = exogeneous variables,

Y = endogenous variable,

and the information sought is the $E\beta_i$ and the variance/covariance matrix of β.

A simple example illustrates. Suppose a system under study has two exogeneous variables and one endogeneous variable.
Using the relationships above yields:

$$[31] \quad E(Y|X_1, X_2) = X_1E\beta_1 + X_2E\beta_2,$$

$$[32] \quad V(Y|X_1, X_2) = X_1^2V\beta_1 + X_2^2V\beta_2 + 2X_1X_2C(\beta_1\beta_2) + \sigma^2e.$$

The questions asked of the expert are of the form: "What is your expectation of Y given X_1 = (some value) and X_2 = (some value)?" Two such questions, when answered, provide all that is necessary to have a solution to equation [31], but how about [32]? The first step is to have the expert provide variance information, i.e., Y ± r, about Y as the questions are being asked. So, with four sets of questions both [31] and [32] could be solved. However, four responses provide an opportunity for the expert to become incoherent in the responses offered.

Because it is difficult for an expert to provide estimates on the variance/covariance of the β terms, several possibilities exist as a solution to this problem. The first is what shall be called "Leamer's ellipse of all possible posterior expectations."[2] The second is to assume that the variance/covariance matrix = $\sigma_\beta^2 I$; i.e., all covariance terms = 0. If that is the case, the priors model can be made conditional on σ_e^2 and two sets of questions are all that would be required to provide unique solutions to both [31] and [32]. Yet a third possibility is to follow the procedures outlined by Zellner (1971, pp. 41-53) for specifiying priors to represent "knowing little," one of the most difficult and controversial aspects of the Bayesian approach to inference. That is the approach used for the prior opinions elicited here. (See Appendix D for the specific methodology.)

The elicitation questionnaires used for both the USAFA and the UofU,MBA are included for reference.

USAFA Elicitation Questionnaire

I am doing research on attrition, through the use of an educational production function, at institutions of higher learning. Would you please take a few moments and answer the following hypothetical situation questions based on your past experience with the educational process? Your answers will be extremely helpful in this research effort. An example of the desired format for the answer along with definitions is provided before the situations begin.

Example:

GIVEN:		DEFINITION OF GIVEN:
SCORE:	1000	The graduating class (G.C.) average on the SAT and SAT equivalent, sum of all parts for the whole class upon college entrance.
RSCORE:	950-1025	Range of G.C. scores on SAT or SAT equivalent, upon college entrance.
LDRSHIP:	1600	G.C. Ave. of the leadership measure.
PHYSICAL:	500	G.C. Ave. of the physical measure.
NS:	1000	Number of students beginning school with the G.C.
S/F:	8	Ave. student-faculty ratio for the four years the G.C. is at the Academy.
F/Q:	30	Faculty quality as measured by the percent of faculty who have a Ph.D. degree. Averaged over the four years G.C. is at the Academy.
EF:	8	Experience of faculty--measured in years of military service. Averaged over the four years the G.C. is at the Academy.

YOUR RESPONSES:	The number of students you would expect to complete each year at the Academy, given the characteristics specified above.

FIRST YEAR:	850 plus or minus 10	SECOND YEAR:	750 plus or minus 10
THIRD YEAR:	700 plus or minus 8	GRAD:	675 plus or minus 8

The plus or minus has the following meaning: The range calculated by taking two times the stated plus or minus value captures the actual number of students you expect to complete each year and subsequently graduate, (given those characteristics,) with 95% accuracy; i.e., you expect to be accurate 95% of the time when specifying that 659-691 of a class with those characteristics will graduate.

SITUATION

		#1	#2	#3	#4	#5	#6	#7	#8
	SCORE:	1180	1225	1200	1210	1220	1200	1250	1235
	LDRSHP:	1600	1500	1450	1800	1700	1775	1500	1625
G	PHYSICAL:	500	350	625	550	600	750	650	575
I									
V	NS:	1000	1100	1400	1200	1250	1150	1300	1325
E									
N	S/F:	7	7.5	8	15	6	7	8	10
	F/Q:	20%	20%	20%	40%	35%	30%	30%	33%
	EF:	8	9	10	9.5	11	7	8	8.5
	RSCORE:	800	725	740	680	695	710	750	700

YOUR
RESPONSES:

FIRST
YEAR:

SECOND
YEAR:

THIRD
YEAR:

GRAD:

Are there any variables which you feel are irrelevant in every situation? If so, which ones?

Thank you for your time and effort in answering these questions.

UofU MBA Elicitation Questionnaire

I am doing research on attrition, through the use of an educational production function, at institutions of higher learning. Would you please take a few moments and answer the following hypothetical situation questions based on your past experience with the educational process? Your answers will be extremely helpful in this research effort. An example of the desired format for the answer along with definitions is provided before the situations begin.

Example:

GIVEN:		DEFINITION OF GIVEN:
SCORE:	1100	The MBA two-year graduating class (G.C.) average of (GPA x 200) + GMAT, upon entering the MBA program.
AGE:	23.5	Average age of students in the G.C. when they started the MBA program.
NS:	50	Number of students beginning school with the G.C.
RS:	100	The range of SCORE for an entering class figured from the lowest to the highest for each particular class.

YOUR RESPONSE:	47 plus or minus 1	The number of students you would expect to graduate from a class having the characteristics specified above.

The plus or minus has the following meaning: The range calculated by taking two times the stated plus or minus value captures the actual number of students you expect to actually graduate, (given those characteristics,) with 95% accuracy; i.e., you expect to be accurate 95% of the time when specifying that 45-49 of a class with those characteristics will graduate.

SITUATION

		#1	#2	#3	#4
	SCORE:	1100	1050	1000	1150
G	AGE:	22	23	23.5	24
I					
V	NS:	40	50	45	48
E					
N	RS:	100	75	80	50

YOUR
RESPONSES:

NUMBER OF
GRADUATES:

Are there any variables which you feel are irrelevant in every situation? If so, which ones?

Thank you for your time and effort in answering these questions.

Summary

These elicitation questionnaires were tendered to three personnel involved with the admissions process at the USAFA and to one at the UofU respectively. The results follow in Tables 15 and 16.

Table 15--Results of USAFA Elicitation

Situation	N_f for Expert #1	N_f for Expert #2	N_f for Expert #3
1	800	800	750
	700	700	650
	650	650	620
	620	600	600
2	800	950	891
	725	875	781
	675	800	748
	600	775	726
3	1200	1300	1064
	1100	1200	924
	1000	1150	882
	950	900	854
4	1050	1100	936
	950	950	816
	900	850	780
	850	800	756
5	1100	1150	988
	1000	950	862
	900	875	825
	850	825	800
6	1075	1000	874
	1000	900	759
	900	850	725
	850	800	702
7	1150	1200	1105
	1050	1050	975
	950	1050	936
	900	1000	910
8	1170	1200	1100
	1050	1100	967
	950	1000	927
	900	950	901

Table 16--Results of UofU,MBA Elicitation

Situation	N_ξ for Expert
1	25
2	30
3	20
4	32

Notes to Appendix A

1. Much of the material for this appendix was taken from Joseph B. Kadane, James M. Dickey, Robert L. Winkler, Wayne S. Smith, and Stephen C. Peters, "Interactive Elicitation of Opinions for a Normal Linear Model," Journal of the American Statistical Association, December 1980, 75, 845-54.

2. See Edward E. Leamer, Specification Searches, New York: John Wiley & Sons, Inc., 1978, 127-9.

APPENDIX B

MAJOR STUDIES IN ATTRITION

Some of the major studies performed on attrition were previously referenced in Chapter II. They are addressed here in greater detail to provide a feel for the methodology employed as well as support for the conclusions on university attrition. One additional study, that by Martin Katzman, is also included here.

Astin (1975)

The Astin Study is important because it is one of the first on attrition research to employ longitudinal design (a cross section of time series data and the tracking of individual students over several years) and utilize more than one institution. Such longitudinal data make possible the comparison of environmental experiences of dropouts and persisters and the use of a variety of institutions allows examination of the possible impact of institutional characteristics. The source of data used by Astin was 243,156 beginning freshmen students selected at random from 358 two-year and four-year institutions in the fall of 1968. The follow-up was comprised of samples of 300 students from each institute--approximately 101,000 respondents--in the late summer and fall of 1972. Of the questionnaires returned, 41,356 were properly completed and subsequently used in the study.

The Astin-used reasons for dropping out of college were previously presented in Chapter II in Table 4. His major conclusion is well represented by the following statement and Table 17 which shows the relationship of high school grades to subsequent persistence in coll ge.

> The most "dropout prone" freshmen are those with poor academic records in high school, low aspirations, poor study habits, relatively uneducated parents, and small town backgrounds. Dropping out is also associated with being older than most freshmen, having Prostestant parents, having no current religious preference, and being a cigarette smoker. . . . By far the greatest predictive factor is the student's past academic record and academic ability. Next in importance are the student's degree plans at the time of college entrance, religious preference, followed by concern about college finances, study habits, and educational attainment of parents.
>
> [Astin, 1975, pp. 45-60]

Gustavus (1972)

The significance of the Gustavus study is in the attempt to introduce student success as an ordinal concept. This concept is depicted in Figure 10. For his sample he used students at Florida State University during the Winter Quarter - 1970. He defined successful students as persisters for four straight years of college; readmitted students as

Table 17[a]--Relationship Between Grades and University Persistence

High School Average Grade	Percentage of Students Who Persist	Stopout	Dropout
A or A+	87	6	7
A-	82	7	11
B+	77	8	15
B	66	11	23
B-	62	13	25
C+	52	13	35
C	44	13	43

[a]Data extracted from Astin, Preventing Students from Dropping Out, Table 5, p. 31.

Dropout (least successful)	Readmitted Student	Nondropout (most successful)

Figure 10. Spectrum for College Continuation

full-time students during the quarter under study who had been readmitted at the beginning of that quarter, had been out of school for at least one quarter, and not yet received a collegiate degree; and dropout students as undergraduates who had withdrawn formally at least two years previously and not been readmitted to any university. He accomplished two comparisons, one on background characteristics and one on academic motivation and vocational commitment. For background variables he used age at matriculation, sex, father's occupation score, father's education, mother's education, hometown size, and high school grade point average. In this first comparison, only father's educational attainment was found to exhibit any statistical significance to the degree of success. The variables for the second comparison were divided between academic and vocation. Academic motivation included student's expressed attitude, number of reported hours per week spent studying outside of class, and student plans for graduate school, while vocational commitment used two variables, whether or not the student had decided on a major field of study when first entering college and the number of changes made in academic major.

His conclusions can be grouped into three basic classes:

1. Very few differences were found between successful students, readmitted students, and dropouts with regard to background characteristics.

2. For lower classes (freshmen and sophomores), readmitted

students were generally more academically motivated and vocationally committed than dropouts.

3. For upper classes, the same trend as in conclusion 2 was observed but the readmitted students were even more motivated and committed than the persisting students.

Iffert (1958)

As with the Astin study, this report has already received a great deal of discussion in this Chapter II. Iffert's report was designed to address three separate questions. First, what is the college dropout rate in relation to type of institution, economi status of family, motivation of student, academic performance, amount of student self-help, participation in extracurricular activities, and residence? Second, what are the reasons for changing and dropping from college? Third, what are the implications for universities? The study was based on records and reports of students who entered college as full-time freshmen in the fall of 1950.

A total of 13,700 men and women from 155 institutions were studied. Some of the findings have already been given. Others include:

1. A near majority, 49.1%, of the dropouts quit school before the start of the second year. Another 27.0% dropped sometime during the second year, leaving only 26.9% to drop during the last two years of school.

2. The top 20% of the high school graduating class contributes 42% of college enrollees and 32% of college dropouts. That means 30.5% of those in the top fifth of their class in high school and who went on to college will quit.

3. Referring to the students who graduate in the upper half of

their classes in the secondary schools in the United States, he said, "about one-half go to college on a full-time basis and about three-fourths of them eventually receive a baccalaureate degree," (Iffert, 1958, p. 99).

4. Every effort to find an association of sufficient magnitude to support the hypothesis that "the stronger a student's motivation, the better are his chances of remaining in college," failed. This in spite of the fact that the hypothesis has been ". . . advanced by many writers and has been supported by evidence," (Iffert, 1958, p. 29).

Katzman (1971)

Though this study appears irrelevant to the problem addressed in this dissertation, it is included in the review of the literature for one significant reason. That is the fact that his study was performed as an educational production function where one output was retention of students, thus establishing a possibility for future works using the production function approach. His study was performed in Boston on elementary school children from grades two through six in all local school districts. Three separate areas of output (AO) were used with each area having two measures. One such AO was "holding power" with the two measures being described as the rate of average daily attendance and the rate of continuation of elementary school graduates through high school. These two measures represent retention of students. The independent variables fit into one of three classes: (1) school expenditures, (2) teacher and institutional inputs, and (3) social class and racial variables. Using regression analysis techniques, he found that elementary school resources and teacher inputs had the most significant impact on continuation of students through high school, (Katzman, 1971, p. 60).

APPENDIX C

DETAILED PRODUCTION FUNCTION STUDIES

This appendix details the works of five authors or sets of authors who have performed a study on the economics of education through the use of an educational production function. It provides much greater detail than that attributed to those studies appearing in Chapter II in that inputs, outputs, methodologies and results are provided, often in tabular form.

Samuel Bowles (1970)[1] is one of the many who have done further work using data from the "Coleman Report." His production function was developed using the data for black students enrolled in the twelfth grade during the fall of 1965. The variables he elected to use for the empirical implementation of the model are depicted in Figure 11. A total of thirty-six variables were tested for significance. His estimate of the statistically significant portions of the educational production function appears in Table 18. He confirmed his own assertion (which he readily documented),[2] that teacher quality, as measured by Teacher's Verbal-ability Score, was the "single most important school input." As an explanation for the small explained variance, Bowles pointed to the failure to specify adequately a model of school achievement and also admitted to the shortcoming of failing to include some important influences on learning, such as school policy or community interest in support for education.[3]

The form and specification of the educational production function

DEPENDENT VARIABLE:
Verbal achievement test score

INDEPENDENT VARIABLES:

Nonschool Environment
- Consumer durables in the home
- Reading material in the home
- Parent's educational level
- Foreign language at home
- Urbanism of background
- Preschool attendance
- Number of siblings
- Family stability

General School Environment
- Proportion of students transfering in and out
- Number of twelfth grade students in school
- Number of foreign language courses
- Comprehensiveness of curriculum
- Average time spent in guidance
- Promotion of slow learners
- Extracurricular activities
- Accelerated curriculum
- Number of math courses
- Length of academic day
- Amount of homework
- Teacher turnover
- Days in session
- Tracking

Teacher Quality

Quality of college attended	Degree received
Verbal ability score	Experience
Socioeconomic status	Localism
Number of absences	Salary

Teacher Quantity
- Total pupils in school per total teachers in school

School Facilities
- Volumes per student in the school library
- Science laboratory facilities

Student Attitudes
- Student sense of control over environment
- Student self-concept

Figure 11. Variables Used by Samuel Bowles

Table 18[a]--Production Function Developed by Samuel Bowles

Independent Variable	Coefficient	t-value
1. Reading material in the home	1.9284	2.5847
2. Number of siblings	1.8512	4.3411
3. Parents' educational level	2.4653	4.4660
4. Family stability	0.8264	1.6938
5. Teacher's verbal-ability score	1.2547	7.1970
6. Science lab facilities	0.0505	2.5821
Constant	19.4576	5.1887
R^2	0.1708	
$\|X'X\|$	0.6628	
N	1,000	

[a]Developed from data in Bowles (1970, Table 5, p. 42).

developed using the Coleman Report data were further tested on two different samples of 1,000 twelfth grade students each in the North and the South. Both test samples along with the original production function of 1,000 black twelfth grade students are included in Table 19.

His conclusions are:

(1) The estimated effects of different schools upon scholastic achievement are quite limited.

(2) A uniform improvement of 10% in all school inputs would raise achievement by 5.7%.

(3) Though he feels his results are encouraging, he also declares that we are still a long way from estimating a satisfactory production function due to the inability to measure or the inadequacy of output measures.

(4) The major contribution of his production function was the successful identification of a number of school inputs which do seem to affect student learning.

Jesse Burkhead, Thomas G. Fox, and John W. Holland (1967)[4] conducted a unified survey of 39 Chicago schools, 22 Atlanta schools, and a subsample of 177 schools from the Project TALENT sample. The unit of analysis was the individual high school within the large-city system. Their study had a three-fold purpose. They proposed to examine the allocation of resources and trace relationships between allocation levels and the resulting outputs of the schools. They wanted to explore and measure the influence of input factors on the output of public education. And they suggested procedures for the measurement of input and output relationships in public high schools. They examined Chicago and Atlanta to determine the economic structure of education therein and

Table 19[a]--A Comparison of Bowles' Developed Production Functions

Independent Variable	Original Coef.	Original t-value	Northern Test Coef.	Northern Test t-value	Southern Test Coef.	Southern Test t-value
1. Reading material in the home	1.928	2.585	1.279	1.601	1.841	2.629
2. Number of siblings	1.851	4.341	1.660	3.700	1.794	4.438
3. Parents' educational level	2.465	4.466	2.655	4.626	2.185	4.181
4. Family stability	0.826	1.694	0.899	1.675	0.823	1.858
5. Teacher's verbal-ability score	1.255	7.197	0.721	3.193	1.097	6.593
6. Science laboratory facilities	0.051	2.582	0.059	2.137	0.027	1.724
7. Days in session	-	-	0.189	1.971	-	-
Constant	19.458	5.189	-2.585	-0.146	20.373	6.247
R^2	0.171		0.090		0.196	
$\lvert X'X \rvert$	0.663		0.730		0.519	
N	1,000		1,000		1,000	

[a]Developed from Bowles (1970, Tables 5, A.4 and A.5, pp. 42, 54, 55).

then compare their findings with the interdistrict studies based on data from Project TALENT.

In the 1961-62 school year, there were 103,509 students in average daily attendance in 52 public high schools in Chicago. The 39 high schools which Burkhead et al. examined were comprehensive in nature and enrolled about 55 percent of all Chicago high school students. They used four separate output measures: (1) a composite test score taken from two administrations (one each in the fall and spring) of several aptitude and reading examinations, (2) percentage of students employed after school hours, (3) percentage of students planning to continue full-time education after graduation from high school, and (4) dropouts, expressed for each high school as a ratio of voluntary dropouts to the adjusted membership of the total studentbody.

Inputs consisted of status and school input and process variables. The status variables were: (1) median family income, (2) median years of education of persons twenty-five years old and older, (3) percentage of population nonwhite, (4) percentage of high school students attending nonpublic schools, (5) percentage of white collar workers in the male labor force, and (6) percentage of housing classified as unsound.

School input and process variables included: (1) building age, substituted for the value of buildings, (2) teacher man-years per pupil, (3) administrative man-years per pupil, (4) auxiliary man-years per pupil, (5) textbook and library expenditures per student, (6) materials and supplies expenditures per student, (7) an aggregate measure of resource input--current expenditures per pupil, (8) average class size, (9) percentage of students enrolled in vocational classes, (10) median teacher age, (11) median teacher experience in years, and (12) proportion of teachers with M.A. or higher degrees.

Correlation analysis was employed with the primary result being that test scores as an output proved to be the most amenable to analysis with the particular model developed. Family income was positively related to reading and verbal skills. Teacher experience and teacher salary were both associated with positive outcomes. The outputs post high school continuation and dropout rate were less susceptible to analysis. When using the dropout measure, family income was a significantly negative factor. The dropout rate was not associated with the experience of the teacher, teacher's education, or student-teacher ratios. The size of the high school was uniformly unimportant as an educational variable in Chicago.

The general *institutional characteristics* of the schools in Atlanta were similar to those in Chicago. Therefore, they attempted to use the same model as had been used in Chicago with as few changes as possible. Of the twenty-two Atlanta schools, seventeen were for white students and five were for black students. The white schools enrolled 16,276 and the black schools enrolled 9,802 students. The findings in Atlanta were also similar to those in Chicago in many respects. The major determinants of school performance were factors external to the school itself, such as family income and family housing conditions. Here, as in Chicago, there was a high negative correlation between family income and the dropout rate.

Although the Project TALENT sample consisted of 206 high schools with 49 variables, not all observations were complete for all schools. Therefore, Burkhead and his associates used data such that 177 high schools could be studied. The basic data included in TALENT consisted of ten socioeconomic variables, eighteen test scores, and twenty-one school characteristics. The schools sampled in Project TALENT came from communities having a population between 2,500 and 25,000 and only one public high school.

The output used for comparison with the previous two large-city school districts included a twelfth grade reading test score, a dropout rate, value-added approach--difference between twelfth and tenth grade reading scores, and college attendance (continuation). For inputs, the number of books in the school library was used as a substitute for library expenditures in the large-city studies.

They found that their model was ineffective in analyzing dropouts for small communities, nor was it capable of producing satisfactory answers concerning the continuation of high school students into college. Their study of the Project TALENT data did show family income, teacher experience, and teacher salary to be significant positive variables when examining the other two measures of output.

Martin T. Katzman (1971)[5] performed a study in the Boston city school districts using elementary school students from grades two through six. Three separate areas of output were used. Each area had two measures. The first area was cognitive ability gains and was measured first by the difference in median reading scores between a specific district's second and sixth graders, the largest range available by district. The second measure of cognitive ability was the median level of math competency among fifth graders, the only group for which such scores were available. The second area of output was previously described in Chapter II. It used the rate of average daily attendance and the rate of continuation of elementary graduates through high school as the two measures of holding power. The third output area was titled academic achievement. Katzman used the percent of sixth graders who took the Latin School Exam and the percent of those sixth graders passing the exam as the two measures of this output. Figure 12 outlines all of the variables he used in his model.

Initially, Katzman performed six regressions, one for each output measure of student performance, against expenditures and social class, finding insignificant results in all cases. As a second approximation, student performance was regressed against all physical measures of school inputs and social class. The coefficients for these regressions were consistently higher than for the corresponding expenditure regressions. However, at most only two inputs were significant in the expected direction in any of the six equations.

Katzman arrived at five conclusions from this first effort.

(1) Each output measure differed significantly from the others in the amount of variation explained by the production function equation when using identical independent variables.

(2) No school input had a consistently significant coefficient in every regression.

(3) In every regression, teacher turnover had a negative effect on performance, and, in all but one, increasing enrollment had a positive although insignificant effect on performance.

(4) There existed a positive relationship between social class and student performance.

(5) "Either expenditures are a poor surogate for 'true' school resources or that resources have little or no impact on performance."[6]

DEPENDENT VARIABLES:
- Range (second-sixth grade) of median reading scores
- Fifth grade median level math competency
- Rate of average daily attendance
- Rate of continuation through high school
- Percent of sixth graders taking Latin School Exam
- Percent passing Latin School Exam

INDEPENDENT VARIABLES:
- School Resources:
  - Current school expenditures
  - Instructional expenditures
- School Inputs:
  - Percent of teachers accredited
  - Percent of teachers with masters degree plus
  - Percent of teachers with over ten years experience
  - Percent of students in uncrowded classrooms
  - Pupil-to-teacher ratio
  - Annual rate of teacher turnover
  - Number of students per school district
  - Age of facilities
- Social Class and Racial Variables:
  - Median family income
  - White collar workers
  - Adult median school year
  - Number adults completing high school
  - Median contract rent
  - Percent white students
  - Percent population white

Figure 12. Variables Used by Martin Katzman

Katzman then proceded with a stepwise regression algorithm in an attempt to select that subset of inputs which best predicts performance as indicated by the standard error of the estimate. Such a procedure included those independent variables whose coefficients had a t-value greater than or equal to some prespecified value and removed those variables already entered whose t-value fell below that same value. In his words, "the 'best' regression equations were obtained."[7] The results of his best linear model are shown in Table 20. As this procedure

Table 20[a]--Katzman, Best Linear Regression Model

Variable	Attend $R^2=.13$	Contin $R^2=.40$	Reading $R^2=.45$	Math $R^2=.67$	L.T. $R^2=.51$	L.P. $R^2=.38$
	Performance Measure[b]					
Accredited	0.064	0.059		1.410	0.309	
t-value	2.000	-		2.981	2.472	
Experienced			1.360	0.891		0.102
t-value			3.163	1.945		1.214
Masters	0.029	-0.068		-1.079	0.155	
t-value	1.036	-1.619		-2.398	1.360	
Turnover	-0.108	-0.074	-1.110	-1.776	-0.200	-0.241
t-value	-3.086	-1.396	-2.018	-3.469	-1.429	-2.231
Uncrowding			0.523			0.180
t-value			1.494			2.609
S/T ratio		-0.310				
t-value		-2.296				
Enrollment		0.004	0.015		0.004	0.004
t-value		4.000	1.071		1.000	1.333
Fac. age			0.291	-0.898		
t-value			1.000	-3.151		
Wh. collar	-0.030	0.155	1.190	1.582	0.582	0.231
t-value	-1.034	3.523	2.429	3.395	4.932	2.381

[a]Data adapted from Katzman (1971, Table 3.8, p. 58).

[b]Attend = rate of average daily attendance; Contin = rate of continuation of elementary graduates through high school; Reading = difference in median reading scores; Math = fifth grade median math score; L.T. = percent of sixth graders who took the Latin Test; and L.P. = percent who passed the Latin Exam.

relates to attrition when measured by the continuation output, Katzman (1971, p. 60) found that elementary school resources did have an impact on a student's continuation through high school.

Charles R. Link and Edward Ratledge (1979)[8] did research which would help uncover the importance of school inputs versus home characteristics as determinants of student performance.

> The Coleman Report, originally undertaken to examine the extent of racial discrimination in public schools in the United States, generated a substantial interest in the determinants of achievement. Unfortunately, the plethora of achievement-related papers subsequent to the Coleman Report has not produced a consensus on such crucial issues as the importance of school inputs vis-a-vis home background as determinants of student performance on standardized tests, the importance of alternative educational outputs, or the proper techniques for estimating the equation.
> [Link and Ratledge, 1979, pp. 98-9]

In their paper, Link and Ratledge examined the determinants of reading achievement for 500 fourth-graders in the Wilmington, Delaware School District circa 1969-70. Four characteristics of their study made it unique. First, each student's characteristics were matched with those of the respective teacher. Second, intelligence quotient (IQ) information for each student in the sample was available from an IQ test administered in the fall of 1969. Third, a reading pretest was given to the students at the beginning of the school year, September 1969, which allowed the researchers to account for all inputs which had occurred prior to the fourth grade. Last of all, a questionnaire was given to the students, also at the beginning of the fourth grade year. On the basis of those questions, variables were created representing numerous motivational and perceptional attributes of each of the students.

These attributes represented the main contribution of this study. The two important variables were the student's perception of respective teacher's and parents' expectations for that particular student. All variables were grouped into three basic classifications: student, teacher, and classroom characteristics. The dependent variable was the grade equivalent score on the reading portion of the California Test Bureau Comprehensive Tests of Basic Skills which was administered to the students at the end of the class year in May 1970. The input for student IQ was based on the California Test of Mental Maturity which had been administered to the students in October 1969. The seventeen variables along with the results of the study are presented in Table 21.

The most notable finding of the Link and Ratledge study was the tremendously significant contribution to a student's reading test score by the student perceived expectations of parents and teachers. "This result suggests that there exist previously untapped nontraditional teacher inputs which may be crucial resources in the educational process."[9]

The last study examined in detail was one performed by Alexander W. Astin (1968).[10] This study closes the chapter because it is one of very few to appear on the production of higher education and it is the only one to have a qualitative dimension.[11] His study utilized a sample of 669 students drawn from the freshman classes entering a stratified national sample of 248 accredited, four-year colleges and universities in the fall of 1961. However, to be included in the study, each subject had to have met four criteria:

(1) He must have been among the random samples of approximately 250 students at each college who were selected for a follow-up study conducted in 1962.

(2) The institution of attendance was one of the thirty-eight in

Table 21[a]--Link and Ratledge, Variables and the Coefficients

Insignificant Variables		Significant Variables	
Variable Description	Coefficient (t-value)	Variable Description	Coefficient (t-value)
Class size	0.005 (0.310)	Student perceived teacher expectations	0.506 (5.240)
Teacher education:			
BS	0.121 (0.730)	Student prereading test score	0.603 (13.460)
BS + 30	0.226 (0.880)	Student perceived parent expectations	0.227 (3.130)
MS	0.367 (1.670)	Student IQ	0.035 (8.410)
Teacher white	0.139 (1.520)		
Teacher experience	-0.003 (0.740)		
Class at least 60% black	-0.047 (0.400)		
Student white	-0.168 (1.670)		
Student male	-0.022 (0.290)		
Student preference for race of teacher:			
met	0.014 (0.120)	Constant =	0.891 (1.120)
don't care	0.127 (1.200)	Adjusted mean R^2 =	0.64
Student's father professional	0.228 (1.130)	S.E.E. =	0.8296

[a]Data taken from Link and Ratledge (1979, Table 1, p. 106).

the sample which administered the area tests from the Graduate Record Examinations (GRE) to its seniors in 1965.

(3) The student had to be positively identified by name among those graduates from whom GRE scores were available.

(4) The student must have taken the National Merit Scholarship Qualifying Test (NMSQT) while in high school, and his scores obtained from the files of the National Merit Scholarship Corporation.

The final sample included students from thirty-eight institutions; thirty-two of which were liberal arts colleges, five were universities and one was a teachers college.

The variables used included the following student inputs:

(1-6) Scores on the NMSQT - five subsets plus a composite score.

(7) Sex.

(8-16) High school grades, A, A-, through C.

(17) Size of high school class.

(18-35) Dichotomous scores on eighteen nonacademic achievements.

(36) Father's educational level.

(37-52) Father's educational field.

(53-58) Student's highest degree planned.

(59-73) Intended field of study.

(74-103) Career choice.

School inputs were:

(1) Selectivity (an estimate of average academic ability of entering students.)

(2) Per-student expenditures for educational and general purposes.

(3) Number of books in library.

(4) Number of books in library per student.

(5) Student-faculty ratio.

(6) Percentage of faculty with a Ph.D. degree.

(7) Total affluence--average based on school input measures two to to six above.

(8) Degree of academic competitiveness.

(9-12) Four types of university control.

(13-18) Type of institution.

(19-22) Geographic region of the United States.

(23-26) Type of college town.

(27) Undergraduate enrollment (number of students).

(28) Percentage of men in the studentbody.

(29-34) Curricular emphasis.

(35-69) Thirty-five measures of the college environment derived from the Inventory of College Activities.

The output measure was the individual student's score on one of the area tests of the GRE administered in 1965.

Astin tested two hypotheses. The first was that the academic excellence of the undergraduate institution has a positive effect on the student's intellectual achievement. Second was the extent of the positive effect of institutional quality on intellectual achievement is proportional to the student's academic ability. The first hypothesis was concerned with the main effects of institutional excellence on intellectual achievement. The second dealt with the interaction effects of institutional quality and student ability on intellectual achievement. The statistical technique used to test these hypotheses consisted of a three-stage, stepwise, linear regression procedure. During the first stage, the 103 student-input variables entered the equation. In the second stage, the 69 college environmental variables, including the measures of institutional excellence were permitted to enter. The last stage permitted the two interaction terms to enter the equation. Three such three-stage analyses were performed, one for each of the area tests of the GRE.

Astin was unable to find much support for the hypotheses put forth. The second stage of his three-stage analysis failed to reveal any clear-cut pattern of institutional characteristics which either fostered or inhibited student achievement. Regarding the individual student, Astin said:

> Of the student's characteristics at the time he enters college, the most important single determinant of his level of achievement as a college senior was his academic ability as measured during high school. . . . Next to academic ability and sex, the most important predictors of undergraduate a-chievement were the student's intended field of study and his career choice at the time he entered college.
>
> [Astin, 1968, p. 665-6]

Notes to Appendix C

1. Information for this section taken from Samuel Bowles, "Towards an Educational Production Function," in W. Lee Hansen, ed., *Education, Income, and Human Capital*, New York: National Bureau of Economic Research, 1970, 50-4.

2. Ibid., 43.

3. Ibid., 45.

4. Information for this section taken from Jesse Burkhead, Thomas G. Fox, and John W. Holland, *Input and Output in Large-City High Schools*, Syracuse: Syracuse University Press, 1967.

5. Information for this section taken from Katzman (1971).

6. Ibid., 55.

7. Ibid., 57.

8. Information for this section taken from Charles R. Link and Edward C. Ratledge, "Student Perceptions, I.Q. and Achievement," *Journal of Human Resources*, Winter 1979, XIV, 98-111.

9. Ibid., 109.

10. Information for this section taken from Astin (1968), 661-8.

11. Cohn (1979), 188.

APPENDIX D

MULTIPLE LINEAR REGRESSION

Multiple Linear Regression techniques are used in deriving the maximum likelihood estimator for the models in this dissertation. The following assumptions apply:

i. The model is specified by $Y = X\beta + e$, where Y is output and is an n x 1 matrix, X represents the independent inputs and is k x n, and e is the error term and is n x 1.

ii. X_i's are nonstochastic. In addition, no exact linear relationship exists between two or more of the independent variables.

iii. a. The error term has an expected value = 0 and a constant variance for all observations.

b. The errors corresponding to different observations are not correlated.

c. The error variable is normally distributed.

Given the assumptions i, ii, iiia, and iiib, Gauss-Markov applies; i.e., the estimators are the best linear unbiased estimators, BLUE. When iiic is added, the estimators are the maximum likelihood estimators (MLE) as well. The MLE of β are the values of β which would most likely generate the observed sample observations of Y_i.

The subjective results are based on the normal-gamma (N-Γ) theory where β is a vector of random variables which is also a N-Γ mixture of conditionally independent, identically distributed normals which are distributed as a t-distribution with 2α degrees of freedom, μ_o location of mean, and τ_o/γ variance. The subjective view of the multiple regression model is:

if $\beta \mid X, \pi \sim N\ (\beta_o, [\pi\tau_o]^{-1} = (\pi_o)^{-1})$, and

$\pi \mid X \sim \Gamma\ (\alpha,\gamma)$; it can be shown that

$$\beta \mid X, Y, \pi \sim N\ ([\pi(X'X + \tau_o)]^{-1}\ [\pi\tau_o\beta_o + \pi X'X\tilde{\beta}],$$
$$[\pi(X'X + \tau_o)]^{-1}), \text{ and}$$

$\pi \mid X, Y \sim \Gamma\ (\alpha + n/2, \gamma + e'e/2)$.

The degrees of freedom are 2α, where α comes from the $\pi \mid X, Y$ statement and is $\alpha + n/2$. The location of the mean is μ_o, where μ_o comes from the $\beta \mid X, Y, \pi$ statement. And the variance τ_o/γ comes jointly from both of those statements, where τ_o is $[\pi(X'X + \tau_o)]^{-1}$ and γ is $(\gamma + e'e/2)$. Therefore, the posterior of $\beta \sim t\ (2\alpha + n, [\pi(X'X + \tau_o)]^{-1}$ $[\pi\tau_o\beta_o + \pi X'X\tilde{\beta}], (\alpha + n/2)(X'X + \tau_o)/(\gamma + e'e/2)$. The following definitions apply to the notation used:

β = coefficient values

$\tilde{\beta}$ = MLE of β

β_o = prior opinions of β

X matrix of independent input variables

π = precision (inverse of variance)

π_o = prior opinion of precision = $\pi\tau_o$

τ_o = some constant prior opinion value

N = normal distribution

Γ = gamma distribution

α = parameter value of Γ

γ = parameter value of Γ

Y = matrix of dependent output variable

n = number of observations

t = t-distribution

e = short notation for $(Y - X\beta)$.

Of course the item of particular interest in the posterior t-distribution is the mean location. That is:

$$[\pi(X'X + \tau_o)]^{-1} [\pi\tau_o\beta_o + \pi X'X\tilde{\beta}].$$

For the USAFA, this will provide a k x 1 matrix representing the posterior estimate of the coefficient values.

Because of the difficulty involved in eliciting prior opinions on the variance/covariance matrix of the coefficient values, the weighting procedure used in this dissertation is similar to those alternatives described by Zellner (1971, pp. 41-53) for dealing with unknown, vague, or otherwise diffuse prior opinions. Therefore, for purposes of the subjective results of this dissertation, the posterior mean location of β is weighted by $\pi(X'X + \tau_o X'X)$. The posterior mean location is specified as $[\pi(X'X + \tau_o X'X)]^{-1}[\pi X'X\tilde{\beta} + \pi\tau_o\ X'X\ \beta_o]$. Various constant values of τ_o are specified in the posterior aggregate model for the USAFA and the UofU,MBA model. However only a value of τ_o = .01 is used on all other USAFA models.

APPENDIX E[1]

EQUATING ACT WITH SAT

Chase and Berritt undertook a study in 1961 to determine whether or not ACT and SAT results could be compared. The study was performed using freshmen from Indiana University. Five achievement exams; Cooperative English Test: C2, Reasoning Comprehension ((1) Level and (2) Vocabulary); the Multiple Aptitude Test ((3) Arithmetic Reasoning and (4) Applied Science and Mechanics); and the Sequential Tests of Educational Progress ((5) Writing); were administered. These five tests were called the anchor test. The class was then randomly divided into two groups. One group took the ACT, the other the SAT. The method employed to arrive at concordant ACT-SAT scores was to parallel ACT and SAT scores which predicted a common anchor test score.

> Specifically, SAT score Y was found to predict anchor test score X. Next, the ACT score Z, which also predicted anchor score X was identified. Then SAT Y was placed concordant with ACT Z.
>
> [Chase & Barritt, 1966, p. 105]

A portion of the favorable results which they discovered is portrayed in Table 8 within Chapter IV.

Notes to Appendix E

1. This appendix is not intended to reproduce either the methodology or the results of the Chase-Barritt study. It is only provided as an insight into the reason why ACT and SAT can be equated with each other. Clinton I. Chase was an associate professor of education at Indiana University, and L. Spencer Barritt was an assistant professor of education at the University of Michigan when their jointly authored article appeared in The Journal of College Student Personnel, 1966.

APPENDIX F

DATA FROM USAFA

Table 22--USAFA Data

Year	SC (÷ 1000)	RC (÷ 1000)	PH (÷ 1000)	LD (÷ 1000)	FQ	FE (÷ 10)	SF (÷ 10)
1958	1.190	.678	.5550	1.6239	.1940	1.25	.57
1959	1.218	.690	.5570	1.6410	.2418	1.29	.75
1960	1.209	.694	.5469	1.5724	.1916	1.14	.70
1961	1.250	.773	.5550	1.6250	.1838	1.03	.67
1962	1.267	.687	.5420	1.6056	.2062	.99	.76
1963	1.266	.620	.5558	1.6225	.2066	1.05	.74
1964	1.277	.690	.5634	1.6365	.1961	1.03	.70
1965	1.276	.627	.5737	1.7600	.2424	1.04	.75
1966	1.277	.648	.5575	1.6359	.2468	1.13	.72
1967	1.280	.702	.5729	1.6382	.2716	1.14	.77
1968	1.269	.702	.5661	1.6322	.3084	1.29	.72
1969	1.261	.731	.5477	1.5958	.3142	1.28	.72
1970	1.238	.671	.5353	1.5956	.2593	1.24	.72
1971	1.243	.703	.5511	1.6163	.2765	1.30	.74
1972	1.246	.731	.5538	1.6141	.2875	1.24	.72
1973	1.238	.715	.5562	1.5944	.2795	1.21	.68
1974	1.235	.738	.5591	1.6084	.2896	1.19	.69
1975	1.209	.820	.5285	1.5767	.2811	1.11	.78
1976	1.197	.720	.5404	1.5728	.2934	1.09	.82
1977	1.208	.760	.5608	1.5883	.2949	1.15	.82
1978	1.212	.730	.5317	1.5913	.3271	1.19	.86
1979	1.240	.710	.5322	1.5885	.3181	1.10	.82
1980	1.219	.770	.5400	1.6094	.2924	1.07	.77
1981	1.213	.750	.5288	1.6081	.3352	1.14	.83
1982	1.216	.810	.5303	1.6174	.3376	1.16	.83
1983	1.215	.720	.5342	1.6212	.3105	1.16	.82
Statistics							
Mean	1.2373	.7150	.5491	1.6151	.2687	1.154	.749
σ	.0277	.0484	.0136	.0359	.0478	.090	.064
σ^2	.0008	.0023	.0002	.0013	.0023	.008	.004
Median	1.2380	.7125	.5524	1.6118	.2803	1.145	.745
Range	.0900	.2000	.0452	.1876	.1538	.310	.290

Table 23--USAFA NS[a]

Year	Freshman	Sophomore	Junior	Senior	Aggregate
1958	.285				
1959	.436	.256			
1960	.668	.366	.239		
1961	.693	.582	.323	.221	1.819
1962	.765	.588	.542	.305	2.200
1963	.733	.675	.555	.512	2.475
1964	.763	.615	.621	.520	2.519
1965	.929	.653	.566	.570	2.718
1966	1.004	.770	.558	.480	2.812
1967	1.019	.852	.716	.537	3.124
1968	1.017	.874	.756	.620	3.267
1969	1.186	.845	.789	.691	3.511
1970	1.383	.962	.738	.756	3.839
1971	1.414	1.131	.848	.713	4.106
1972	1.247	1.069	.960	.774	4.050
1973	1.359	.958	.891	.851	4.059
1974	1.298	1.095	.829	.825	4.047
1975	1.514	1.106	1.009	.770	4.399
1976	1.343	1.227	.945	.935	4.450
1977	1.503	1.077	1.045	.876	4.501
1978	1.446	1.227	.960	.994	4.627
1979	1.389	1.156	1.007	.911	4.463
1980	1.392	1.124	1.014	.921	4.451
1981	1.493	1.168	.958	.901	4.520
1982	1.377	1.257	1.039	.869	4.542
1983	1.370	1.097	1.097	.966	4.530
Statistics					
Mean	1.1164	.9092	.7919	.7182	3.6969
σ	.3557	.2799	.2352	.2134	.8872
σ^2	.1265	.0784	.0553	.0455	.7871
Median	1.2725	.9620	.8385	.7700	4.0500
Range	1.2290	1.0010	.8580	.7730	2.8080

[a]Adjusted number enrolled in thousands.

Table 24--USAFA N_d

Year	Freshman	Sophomore	Junior	Senior	Aggregate
1958	29				
1959	70	17			
1960	86	43	18		
1961	105	40	18	4	167
1962	90	33	30	7	160
1963	118	54	35	13	220
1964	110	49	51	21	231
1965	159	95	86	53	393
1966	152	54	21	10	237
1967	145	96	96	13	350
1968	172	85	65	7	329
1969	224	107	33	8	372
1970	252	114	25	11	402
1971	345	171	74	21	611
1972	289	178	109	20	596
1973	264	129	66	7	466
1974	192	86	59	12	349
1975	287	161	74	14	536
1976	266	182	69	7	524
1977	276	117	51	9	453
1978	290	220	49	13	572
1979	265	142	86	11	504
1980	224	166	113	22	525
1981	236	129	89	25	479
1982	280	160	73	27	540
1983	291	~~117~~	35	10	453
Statistics					
Mean	200.7	109.8	59.4	15.0	411.7
σ	86.2	54.5	28.6	10.4	137.5
σ^2	7433.4	2971.5	818.7	109.1	18904.6
Median	224.0	114.0	62.0	12.0	453.0
Range	316.0	203.0	95.0	49.0	451.0

APPENDIX G

ON SERIAL CORRELATION

The procedure used to adjust the ordinary least-squares regression procedure to obtain efficient parameter estimates involves the use of generalized differencing. Such a procedure alters the linear model into one where the errors are independent. The development of the model as shown by equation [27] (see text Chapter IV) would be a simple matter if the value of ρ were known with certainty. Because ρ is not usually known a priori, three alternative procedures for estimating ρ have been developed, each having certain computational advantages and disadvantages. They are (1) The Cochrane-Orcutt procedure,[1] (2) the Hildreth-Lu procedure,[2] and (3) The Durbin procedure.[3]

The Hildreth-Lu procedure was used in this study and consists of specifying a set of grid values for ρ much like simulation. For each of the estimated ρ-values, the transformed equation was estimated. The equation with the smallest sum of squared residuals was selected as the best equation. Appendix H shows the grid value selected for each equation estimate as well as the results of all statistical procedures which were applied.

Notes to Appendix G

1. For a complete description of the Cochrane-Orcutt procedure, see D. Cochrane and G. H. Orcutt, "Application of Least Squares Regressions to Relationships Containing Autocorrelated Error Terms, Journal of the American Statistical Association, 1949, 44, 32-61.

2. For a complete description of the Hildreth-Lu procedure, see G. Hildreth and J. Y. Lu, "Demand Relations with Autocorrelated Disturbances," Michigan State University Agriculture Experiment Station, Technical Bulletin 276, November 1960.

3. For a complete description of the Durbin procedure, see J. Durbin, "Estimation of Parameters in Time-Series Regression Models," Jounal of the Royal Statistical Society, ser. B, 22, 1060, 139-53. For a more brief treatise on all three of these procedures, see Pindyck and Rubinfeld (1981) 157-8.

APPENDIX H

MODEL RESULTS

Table 25--Classical USAFA Freshman Model

Input Variable	Coefficient (SE)	Stepwise (SE)	Finish[c] (SE)
NS (÷ 1000)	248.7[a] (33)	223.6 (15.6)	751.3[a] (33)
SC (÷ 1000)	-162.92 (264)		
RS (÷ 1000)	-70.14 (127)		
PH (÷ 1000)	-662.1[b] (681)		
LD (÷ 1000)	184.74[b] (213)		
FQ (decimal)	-399.602[b] (302.7)		
FE (÷ 10)	229.34[a] (87)	150.1 (61.5)	
SF (÷ 10)	110.22 (144)		
ADJ R^2	.919	.898	.992
SEE	28.916	27.54	
F-Value	182.03	111.00	323.49
SSRESID	15050.11	17444.98	

Durbin-Watson: 1.926

form: $Y_t = \Sigma X_{it} B_i + e_t$, i = 1 to 8, t 1958 to 1983.

[a]Statistically significant at .95 level.
[b]Statistically significant at .60 level.
[c]Result of N_f equation.

Table 26--Classical USAFA Sophomore Model

Input Variable	Coefficient (SE)	Stepwise (SE)	Finish[e] (SE)
NS (÷ 1000)	198.21[a] (42)	171.77 (19.13)	801.79[a] (42)
SC (÷ 1000)	-188.49 (232)		
RS (÷ 1000)	-138.26[b] (119)		
PH (÷ 1000)	449.37 (525)		
LD (÷ 1000)	-144.04 (192)		
FQ (decimal)	-362.865[c] (252.8)		
FE (÷ 10)	149.45[d] (73)		
SF (÷ 10)	230.80[c] (141)		
ADJ R^2	.899	.768	.995
SEE	26.19	26.23	
F-Value	126.26	80.62	415.88
SSRESID	10974.66	15830.05	

Durbin-Watson: 2.594

form: $(Y_t - \rho Y_{t-1}) = \Sigma(X_{it} - \rho X_{it-1})B_i + e_t$,

$i = 1$ to 8, $t = 1959$ to 1983, $\rho = -.41$

[a]Statistically significant at .95 level.
[b]Statistically significant at .60 level.
[c]Statistically significant at .80 level.
[d]Statistically significant at .90 level.
[e]Result of N_f equation.

Table 27--Classical USAFA Junior Model

Input Variable	Coefficient (SE)	Stepwise (SE)	Finish[d] (SE)
NS (÷ 1000)	128.95[a] (57)	116.70 (22)	871.05[a] (57)
SC (÷ 1000)	265.45[b] (257)		
RS (÷ 1000)	-270.45[a] (123)	-371.46 (106)	
PH (÷ 1000)	-208.05 (527)		
LD (÷ 1000)	124.02 (174)		
FQ (decimal)	146.24 (303.9)		
FE (÷ 10)	-165.41[c] (103)	-85.91 (52)	
SF (÷ 10)	-90.32 (148)		
ADJ R^2	.559	.528	.990
SEE	21.862	19.665	
F-Value	21.47	9.56	210.63
SSRESID	7168.49	7733.87	

Durbin-Watson: 1.584

form: $(Y_t - \rho Y_{t-1}) = \Sigma(X_{it} - \rho X_{it-1})B_i + e_t$,

$i = 1$ to 8, $t = 1960$ to 1983, $\rho = -.081$

[a]Statistically significant at .95 level.
[b]Statistically significant at .60 level.
[c]Statistically significant at .80 level.
[d]Results of N_f equation.

Table 28--Classical USAFA Senior Model

Input Variable	Coefficient (SE)	Stepwise (SE)	Finish[d] (SE)
NS (÷ 1000)	-17.91 (33)		1017.91[a] (33)
SC (÷ 1000)	298.01[a] (101)	311.99 (95.9)	
RS (÷ 1000)	71.33[b] (78)	52.92 (45.9)	
PH (÷ 1000)	-354.47[b] (273)	-451.38 (176.9)	
LD (÷ 1000)	-67.57 (98)		
FQ (decimal)	139.414 (179.3)		
FE (÷ 10)	-76.06[c] (47)	-58.54 (25.4)	
SF (÷ 10)	-51.57 (78)		
ADJ R^2	.444	.311	.998
SEE	9.72	8.67	
F-Value	9.834	3.482	1590.79
SSRESID	1322.67	1352.92	

Durbin-Watson: 2.136

form: $(Y_t - \rho Y_{t-1}) = \Sigma(X_{it} - \rho X_{it-1})B_i + e_t$,

$i = 1$ to 8, $t = 1961$ to 1983, $\rho = -.11$

[a]Statistically significant at .95 level.
[b]Statistically significant at .60 level.
[c]Statistically significant at .80 level.
[d]Results of N_f equation.

Table 29--Classical USAFA Aggregate Model

Input Variable	Coefficient (SE)	Stepwise (SE)	Finish[e] (SE)
NS (÷ 1000)	214.55[a] (43)	155.7 (21.1)	785.44[a] (43)
SC (÷ 1000)	2172.72[b] (2020)		
RS (÷ 1000)	-1220.64[c] (607)	-646.9 (526.6)	
PH (÷ 1000)	-2689.02[b] (2443)		
LD (÷ 1000)	-649.77 (1303)		
FQ (decimal)	-1204.289[d] (841.2)		
FE (÷ 10)	173.91 (295)		
SF (÷ 10)	592.85[b] (447)		
ADJ R^2	.885	.786	.996
SEE	63.764	63.64	
F-Value	191.469	41.343	547.578
SSRESID	56921.19	81003.91	

Durbin-Watson: 2.373

form: $(Y_t - \rho Y_{t-1}) = \Sigma(X_{it} - \rho X_{it-1})B_i + e_t$,

$i = 1$ to 8, $t = 1961$ to 1983, $\rho = -.221$

[a]Statistically significant at .95 level.
[b]Statistically significant at .60 level.
[c]Statistically significant at .90 level.
[d]Statistically significant at .80 level.
[e]Results of N_f equation.

Table 30--Prior Opinions of USAFA Models

Input Variable[a]	Freshman Drop (N_d) Coefficient	Sophomore Drop (N_d) Coefficient	Junior Drop (N_d) Coefficient	Senior Drop (N_d) Coefficient	Aggregate Drop (N_d) Coefficient
NS	-96.12	36.52	10.35	69.62	598.94
SC	-1266.6	-1521.68	763.63	724.04	-1579.23
RS	3041.27	1868	-857.64	-803.66	1200.23
PH	-68.9	-163.87	190.1	39.62	-483.47
LD	-141.55	303.62	-203.71	-159.86	481.8
FQ	0	0	0	0	0
FE	-75.81	194.98	-41.79	-84.55	96.13
SF	0	0	0	0	0

[a]All variables have the same decimal place as the classical models.

Table 31--Posterior USAFA Models[a]

Input Variable[b]	Freshman Drop (N_d) Coefficient	Sophomore Drop (N_d) Coefficient	Junior Drop (N_d) Coefficient	Senior Drop (N_d) Coefficient	Aggregate Drop (N_d) Coefficient
NS	245.3	196.6	127.8	-17.0	218.4
SC	-173.8	-201.7	270.4	302.2	2135.6
RS	-39.3	-118.4	-276.3	62.7	-1196.7
PH	-656.2	443.3	-293.2	-350.6	-2667.2
LD	181.5	-139.6	120.8	-68.5	-638.6
FQ	-395.6	-359.3	144.8	138.0	-1192.4
FE	226.3	149.9	-164.2	-76.1	173.1
SF	109.1	228.5	-89.4	-51.1	586.98

[a]For all models developed, $\tau_o = .01$. The formula (from Appendix D) is $(1 + \tau_o)(\tilde{\beta} + \tau_o\beta_o)$.

[b]Decimal place remains as for classical results.

Table 32[a]--Alternative Posterior Models
Reflecting Belief in Priors

Input Variable[b]	$\tau_o=0$[c]	$\tau_o=.5$	$\tau_o=1$[d]	$\tau_o=2$	$\tau_o=\infty$[e]
NS	214.6	342.7	406.8	470.8	598.9
SC	2172.7	922.1	296.8	-328.6	-1579.2
RS	-1220.6	413.7	-10.2	393.3	1200.2
PH	-2689.0	-1953.8	-1586.3	-1218.7	-483.5
LD	-649.8	-272.6	-84.0	104.6	481.8
FQ	-1204.3	-802.9	-602.2	-401.4	0
FE	173.9	148.0	135.0	122.0	96.1
SF	592.9	395.2	296.5	197.6	0

[a]This table presents posterior coefficient values for the aggregate USAFA model when different τ_o values are specified. It demonstrates that τ_o represents the degree of belief in the prior opinions.

[b]Decimal place remains the same as it was for classical results.

[c]These results are identical to the MLE coefficients found in Table 31.

[d]Specifying a $\tau_o = 1$ is equivalent to specifying a posterior which is a simple linear average between the MLE coefficient values and the prior opinion coefficient values.

[e]These results are identical to the prior opinion coefficients found in Table 33.

APPENDIX I

ON HYPOTHESIS TESTING

Leamer (1978, p. 89) indicates that the significant difference between classical hypothesis testing and the subjective view of the same subject is one of significance. In classical hypothesis testing, a fixed level of significance is concluded as being an acceptable method of summarizing the evidence in favor of or against the hypothesis. Pindyck and Rubinfeld (1981, p. 39) announce that this level is "usually 1 or 5 percent." In the subjective view, meaningful hypothesis testing requires the signficance level to be a decreasing function of sample size. A small demonstration on this power of the function illustrates.

Assume H_0: $S = S_0$

and H_1: $S = S_1$ are the hypotheses being tested. Figure 13 represents the possible choices for the researcher. In hypothesis testing, one wishes to conclude that S_1 is true and in fact have it to be true.

		State of Nature	
		S_0	S_1
Researcher Chooses	S_0	$1 - \alpha$ correct	β or Type II
	S_1	α or Type I	$1 - \beta$ correct

Figure 13. Researcher Choices Available and the Respective Errors

Therefore, $1 - \beta$ represents the power of the function. The greater the power function, the better the decision rule, hence a large $1 - \beta$ is more desirable than a smaller one; i.e., a smaller β value is more desirable than a larger β value.

There are two ways in which this power of the function can be enlarged. Because of the relationship between α and β, one can accept a larger α and thus decrease β, the net effect being an increase in $1 - \beta$, the power of the function. The second method is that of increasing the sample size. The closer the sample comes to representing the universe, the more likely one is to choose S_1 as the real state of nature when in fact it is true, $1 - \beta$ approaches 1.

The bottom line is that researchers should not get caught-up in always selecting $\alpha = .05$ or $\alpha = .01$. In fact, one should not always be content to select a low level of significance and therefore a low probability of a Type I error. Meaningful hypothesis testing requires the significance level to be a decreasing function of the sample size.

Because the sample size in the two sets of data studies herein are relatively small when compared to the university world universe, the significance level (α) can be quite large. That is the reason Appendix H presents α-levels as high as 0.40.

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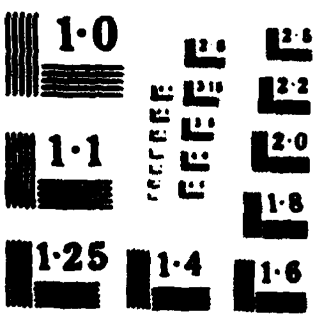
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