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AN ECONOMIC ANALYSIS OF THE COSTS OF INSTRUCTION IN THE MICHIGAN SYSTEM OF HIGHER EDUCATION

By

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ABSTRACT

AN ECONOMIC ANALYSIS OF THE COSTS OF INSTRUCTION IN THE MICHIGAN SYSTEM OF HIGHER EDUCATION

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This thesis examines the instructional cost function in higher education, estimates this cost function for the public institutions in the State of Michigan, tests hypotheses about the nature of this cost function, and discusses the policy implications of the results.

Researchers to date have implicitly assumed that the instructional cost function in higher education is linear in all instructional products, that it exhibits no fixed costs, and that the cost of each instructional product is independent of the output of all other instructional products. Each of these assumptions is examined in this thesis.

Data provided by the Michigan Council of State College Presidents showing expenditures and educational outputs at the departmental level for thirteen institutions in the State of Michigan over a nine year period were used. These data allowed estimation of total cost functions for six disciplines: Business Administration, Education, Engineering, Humanities, Natural Sciences, and Social Sciences.

The estimation of these cost functions was done using weighted least squares multiple regression techniques. And the form of the cost function estimated included, in each case, terms of the second and third power to estimate non-linearity, interaction terms to estimate dependence among the instructional outputs, institutional dummy variables to estimate institutional differences, and a time trend term to estimate cost increases with time.

The conclusions reached through the use of this technique bring into some question the efficacy of the current cost estimation techniques. The assumptions underlying these techniques are found wanting since significant non-linearities are found to exist in the cost function, since significant interactions among instructional outputs exist, and since there is some indication that negative marginal and average variable costs exist within certain ranges. In addition, the conclusions of earlier research are brought into question since there is significant evidence that costs do not increase with student level in all cases. This thesis presents evidence that, in some cases, instructional costs decline as a student moves from undergraduate to graduate work for example.

It is concluded that each department is a unique entity that must be closely examined in order to find the true underlying relationships between student level and costs. And it is also concluded that the use of standard cost accounting techniques have been very misleading in estimating the cost relation, not only for a given department but also for departments in general.

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CHAPTER I

Introduction

This thesis examines the instructional cost function in higher education, estimates this cost function for the public institutions in the State of Michigan, tests hypotheses about the nature of this cost function, and discusses the policy implications of the results.

Researchers to date have implicitly assumed that the instructional cost function in higher education is linear in all instructional products, that it exhibits no fixed costs, that all average variable costs are positive by definition, and that the cost of each instructional product is independent of the output of all other instructional products. This thesis will examine each of these assumptions, all of which are necessary to justify continued use of current cost accounting procedures.[1]

The current cost accounting procedure can be summarized as follows: A) Assign the costs of resources used directly in the production of a given instructional product to that product; B) For each instructional product, sum the costs of inputs used in its production to obtain a total cost for the product; C) Divide the total cost by the quantity of output to obtain an average cost; D) Identify this average cost with the marginal cost for that product by assuming that additional units of the product can be produced for the same cost.[2] In this process, most researchers have assigned all instructional costs to one, and only one, of the instructional products: lower division, upper division, masters, or doctoral for purposes of this research.

While researchers have noted potential inadequacies in the above procedure, this cost accounting procedure has received the widest use[3]; and since the undertaking of these cost studies requires significant resources, the results must be valued by the decision makers in spite of potential problems.[4]

The empirical results obtained through this cost estimation technique conform well to _a priori_ expectations since they show, almost universally, that costs increase with student level[5]: doctoral instruction is more expensive than masters instruction, masters instruction is more expensive than upper division instruction, etc. Decision makers have assumed this relationship _a priori_ because undergraduate faculty, those faculty members who would typically be found teaching at institutions with no graduate programs, are usually less expensive than graduate faculty; class sizes are often larger at the undergraduate level; and undergraduate teaching loads are usually heavier than graduate teaching loads. Graduate programs look more expensive than undergraduate programs, _a priori_, and they are shown to be more expensive through the use of a cost accounting technique which uses the same logic and which uses the same assumptions which led to the *a priori* expectations. It should come as no surprise, therefore, that the empirical results conform to the expectations.

Given that many tasks involved in the instructional process can be performed by a well prepared student as well as by a full-time faculty member, it is possible in some instances to substitute working students for faculty members in the instructional process at much lower cost. In some cases, this substitution requires the expertise of a masters candidate or a doctoral candidate although, in others, an undergraduate student will suffice. Since graduate students with the proper qualifications are often not available to a department unless that department itself offers a graduate program, the existence of such a graduate program may lower some costs of instruction by allowing substitution of less expensive graduate assistants for regular faculty members.

The savings realized due to this use of students should reduce costs of instruction at the level from which the student worker is drawn and not, as present practice would dictate, at the level at which the student works. The results of multiple regression analysis of the cost relationship presented in Chapter III show that these savings and other factors not taken into account by current cost accounting procedures are indeed significant.

Why are perceived costs important?

Before the present cost accounting procedures were developed, *a priori* expectations indicated that costs of instruction would rise as a student advanced, and these expectations were confirmed by the cost accounting procedures used.

Society, the legislator, and the department head assign a value to the various instructional outputs of the system of higher education. Yet, while these will differ and the perception of the costs of producing these outputs will vary depending upon the distance from and knowledge of the production process, a decision is made on the quantity of each output which will be produced. With a given expenditure, the levels of production will not maximize the benefit to society unless the value of the last unit of each output has the same proportionate relation to the marginal cost of each output, or in other words, marginal social benefit (MSB) divided by marginal cost (MC) is equal for all outputs.

$$\frac{MSB_i}{MC_i} = \frac{MSB_j}{MC_j} \quad \text{for all i and j, i and j both produced}$$

The estimation of the social benefit or welfare function is an internalized estimation and will not change as a result of this research. Researchers and decision makers had and have *a priori* expectations regarding the cost relationship, and the cost function has been estimated using cost accounting procedures, and the perception of the cost relationship thus derived is subject to change and may well be changed by this present research. If the assumptions under which costs were estimated are not met, the estimation of the relative costs of various outputs may be far off the mark. If these estimates have been faulty and have been accepted as true, it is unlikely that welfare has been maximized.

The decision making process may not reach dramatically different conclusions based upon reformulation of the relation between costs and outputs; however, very dramatic changes in policy are possible and may be implied. If economies of scale are sufficiently great, institutions should be consolidated. If resource saving interactions do occur among levels of output, graduate education should be spread more evenly among institutions. Costly antagonistic relationships may exist between and among student level production processes which would result in arguments for centralizing graduate programs more than they are at present.

Plan of the thesis

In order to examine the cost function in higher education, Chapter II will develop the nature of that cost function from the underlying model which will necessarily include the production functions and relative prices. These will determine the least cost techniques to use in production of a given output--the cost function. The model will include the budget constraint and welfare function as faced and seen by the department head and legislature so that the bases of rational decision making, yielding maximization of welfare, can be developed. Here the hypotheses to be tested will be developed. These include hypotheses regarding economies and diseconomies of scale, interaction among levels, and relationships among marginal costs.

Using data provided by the Michigan Council of State College Presidents[6], in Chapter III, the author will estimate the instructional cost functions in higher education for six disciplines: Business, Education, Engineering, Humanities, Natural Sciences, and Social Sciences. While this breakdown and the classification of departments into these disciplines can be debated, the groupings used are certainly more homogeneous within disciplines than among disciplines; and the groupings are used approximately as they are here by Michigan State University in forming its colleges, by other institutions, and in various research formats. This chapter presents the tests of the hypotheses developed in Chapter II as well.

It is important to note that the model used is simplified and abstract--no account is taken of political questions in the allocation of funds nor is the interaction among differing perceptions of the welfare function at the various decision levels taken into account--and there is a lack of certain data which has required the use of qualitative rather than quantitative measures to account for quality, non-budgeted research output, and non-budgeted public service output. These simplifications and abstractions limit the results.

Chapter IV presents the research and policy implications of this research.

Summary

Until 1972, economics had not dealt with the question of the nature of the cost and production functions in higher education. The model suggested in 1972 by Fox[7] allowed for the fact that graduate students are often inputs as well as products of the educational and research process, the fact that different levels of students often take classes together, and the liklihood that costs are a function of scale.

Economic theory has much to say about decisions among various outputs and how these decisions should be made in order to maximize welfare given the welfare function, the production functions, the prices of the inputs, and the budget constraint. Economic theory, therefore, has much to say in the case of educational products and the nature of the cost function associated with them. This thesis will examine a segment of what economic analysis can conclude regarding the nature of the cost relationship in higher education for instructional outputs.

This thesis is unique because it is the first to use non-linear, weighted, multiple regression techniques to estimate the instructional cost function in higher education and to investigate the question of interaction among levels, economies and diseconomies of scale, and the underlying nature of the cost function.

The next chapter will employ Jan Tinbergen's[8] theory of economic policy in order to develop a model from which the hypotheses to be tested will be developed.

Footnotes Chapter I

1. These assumptions have not been stated explicitly in some cases; however, they are implied by the technique used. If interactions among levels were present, costs of resources used could not be assigned to one of the joint outputs simply because the resources appeared to be used in producing that output. If the cost function is not both linear and without a constant, then average costs cannot be assumed to equal marginal costs.
2. John H. Powell, Jr. and Robert D. Lamson, Elements Related to the Determination of Costs and Benefits of Graduate Education, (Washington, D.C.: Council of Graduate Schools in the United States and National Association of College and University Business Officers, 1972) page 115.
3. Ibid. Chapter 3.
4. If such studies were not considered to be of value to decision makers, the resources necessary would not be assigned to their production.
5. Gordon Ziemer, et. al., Cost Finding Principles and Procedures: Preliminary Field Review Edition, Technical Report Number 26, (Boulder, Colorado: National Center for Higher Education Management Systems at WICHE, November, 1971) page 214. The two references found in this and footnote two

describe presently utilized costing techniques and proposals for improvement as well as providing the history of such endeavors.

6. Unit Cost Study: Instruction and Departmental Research, 1962-63, 1963-64, 1964-65, 1966-67, 1968-69, 1970-71, (Lansing, Michigan: Michigan Council of State College Presidents, December 19--).

7. Karl A. Fox, editor, Economic Analysis for Educational Planning, (Baltimore and London: The Johns Hopkins University Press, 1972) Chapters eight and nine.

8. Jan Tinbergen, On the Theory of Economic Policy, (Amsterdam: North-Holland Publishing Company, 1952).

CHAPTER II

Introduction

This chapter develops the theoretical model and from it generates hypotheses to be tested in Chapter III through examination of the instructional cost function in higher education which will be estimated there.

The theoretical model is based on the standard economic assumption of the rational, maximizing decision maker. This decision maker will attempt to maximize welfare as he reacts to the resources, constraints, prices, production functions, and the welfare function itself.

Decisions affecting higher education within a state system of institutions are made at many levels; and at each of these levels, a different decision maker or set of decision makers is involved. Each of these decision makers, it is assumed, attempts to maximize welfare. At the state level, successful maximization implies that the last dollar spent on each educational institution and the last dollar spent on other state activities will produce equal increments in welfare. At the institutional level, the last dollar allocated to each department will produce equal welfare increments; and at the departmental level, the last dollar spent on each output will produce equal welfare gains.

Welfare gained, it should be noted, is assumed to be a function of many local factors including individual opportunity costs as well as the nature of the program or output produced. Therefore, the above equalization at the margin does not imply that the marginal cost of teaching students at different institutions need be identical. Differences among students imply differences in opportunity costs for those students, and differences in institutional locations also imply differences in individual and societal opportunity costs. These differences also imply potentially different welfare gains. But it will also be assumed, that within a given department, welfare is not a function of the individuals served.

In addition to assuming the welfare maximizing decision maker at the departmental level--departmental data will be used to estimate the instructional cost function since the department is the level at which many of the decisions regarding the distribution of resources among approved outputs are made or implemented and is the level at which results can be most easily seen--all departments in similar disciplines will be assumed to be on the same production function and face the same set of prices for inputs into the production process. This will imply that these departments will have the same cost function for a given discipline.

The Model

The model developed here will be based upon the theory of economic policy as stated by Jan Tinbergen.[9] Such a model has three parts: 1) a welfare function, 2) production functions, and 3) the other constraints within which the decision maker must operate.

The Welfare Function

Welfare will be assumed to be a function of the outputs of higher education. These outputs are the target variables upon which welfare (W) depends or:

$$W = W\ (O_1, O_2, \ldots, O_m)$$

where there are m outputs.

These outputs (O_i) of academic departments in institutions of higher education include research, public service, and instruction, each of which can be broken down into numerous sub-categories. This thesis deals specifically and in a quantitative manner with the instructional outputs broken down into four sub-categories by student level: lower division (freshmen and sophomores), upper division (juniors and seniors), masters, and doctoral instruction.

The welfare function itself is assumed to be continuous with continuous first and second partial derivatives such that:

$$\partial W / \partial O_i \geq 0, \quad \text{for all i.}$$

$$\text{and} \quad \partial W^2 / \partial^2 O_i \leq 0, \quad \text{for all i.}$$

<u>The Production Functions</u>

There are r potential inputs (I_i). Since it is the case that certain of the outputs of higher education are also inputs[10], let I_{O_i} represent O_i when O_i is used as an input. Separate terminology is necessary since the units of input and output are likely to be different--output in student credit hours (SCH) and input in student work hours.

Output is a function of the inputs, and the production functions, one for each output, are:

$$1) \quad O_1 = O_1 \, (I_{1_1}, \ldots, I_{q_1}; I_{O_{1_1}}, I_{O_{2_1}}, \ldots, I_{O_{m_1}})$$

$$2) \quad O_2 = O_2 \, (I_{1_2}, \ldots, I_{q_2}; I_{O_{1_2}}, I_{O_{2_2}}, \ldots, I_{O_{m_2}})$$

$$m) \quad O_m = O_m \, (I_{1_m}, \ldots, I_{q_m}; I_{O_{1_m}}, I_{O_{2_m}}, \ldots, I_{O_{m_m}})$$

where: a) $q + m = r$,

and b) $(Q_i) \cdot (O_i) \geq \sum_{j=1}^{m} I_{O_{i_j}}$,

and where: Q_i are the maximum proportions of input to output at each student level i or Max (I_{O_i}/O_i).

The value of Q_i limits the amount of input I_{O_i} available from a given quantity of output of instruction at level i. Or, in other words, each student will work as an assistant only a limited amount of time per week and the maximum proportion that the market will maintain between working hours and credit hours on the average at a given student level is represented by Q_i.

Q_i is clearly not fixed in value since it is likely to be a function of the quality of student in a program as well as other factors. For example, very high quality students are more likely to qualify for forms of student aid not requiring work and are therefore less likely to wish to work implying a low Q_i. With a given student population mix and a given student wage rate, (the wage rate or limits are often imposed on a department) there is a maximum amount of student work obtainable, and where O_i is zero I_{O_i} is also zero.

Constraint a) above, $q + m = r$, is simply the statement that there are r outputs of which q are not related to any instructional output and m are related to one of the instructional outputs.

The Other Constraints

The other constraints under which the decision maker in higher education must operate will be assumed to be three:

$$\text{(A)} \quad B \geq \sum_{i=1}^{q} P_i I_i + \sum_{j=1}^{m} I_{O_j} P_{j+q}, \text{ where } I_i = \sum_{k=1} I_{i_k}$$

$$\text{(B)} \quad O_k \leq C_k, \qquad k = 1, \ldots, m$$

$$\text{(C)} \quad Q_i O_i \geq \sum_{j=1}^{m} I_{O_{i_j}}, \qquad i = 1, \ldots, m$$

Where B is the budget imposed on the department, P_i are the prices or wages[11] of the inputs, C_k is a limit on output k imposed from outside the department, and constraint (C) holds where the department is the only source of O_i. The constraints listed in (B) include constraints on curricula, student body size, student body makeup, availability of specialized physical facilities, authorization to offer programs at given levels, and so on, where C_k is the imposed maximum output. All of these constraints must be imposed on the departmental decision maker.

The model can now be summarized as:

1. Aggregate welfare depends upon the quantity of instruction produced.

2. Output is a function of the input levels.

3. Output is constrained by budget, prices of inputs, legal limits on output, other constraints imposed from outside the

department by the college, university, or outside agencies, and by the production functions.

Since this research deals strictly at the departmental level, and since it is typically the case that departments are more limited in their ability to limit their outputs to particular individuals, the assumption that welfare depends upon individuals served has been dropped at the departmental level as noted above. It is clear that welfare is a function of the individuals served but this modification is necessary to deal with the problem at hand because no data on individuals served are available. If this assumption had not been dropped, the welfare function would have read:

$$W = W(O_{1_1}, O_{2_1}, \ldots, O_{m_1}; O_{1_2}, \ldots, O_{m_2}; \ldots; O_{1_n}, \ldots, O_{m_n})$$

for n individuals and m outputs.

If the decision maker does not perceive welfare as a function of the individuals served, then it is legitimate to sum all outputs (O_{i_j}) across individuals to obtain homogeneous output of each type with respect to individuals. For purposes of this research, and most often in reality at the departmental level, the decision maker is assumed to be blind to individuals served and the welfare function returns to its original form:

$$W = W(O_1, O_2, \ldots, O_m)$$

Characteristics of the Model

The following will be characteristics of the model:

A) $\partial W / \partial O_i \geq 0$, for all i.

B) $\partial O_i / \partial I_j \geq 0$, for all i, j.

The above model implies the following total cost function at the departmental level:

$$TC = TC\ (O_1, O_2, \ldots, O_m; P_1, P_2, \ldots, P_r)$$

where O_i is the quantity of output i and P_j is the price or marginal cost of input j. It will be assumed, again to simplify the model, that relative prices remained constant during the period of the study.[12] This assumption allows the restatement of the total cost function as follows:

$$TC = TC\ (O_1, O_2, \ldots, O_m; P^*)$$

where P* is the price level with relative prices constant.

For those programs offered and where no constraints except the production functions are effective, the first order conditions for a welfare maximum at the departmental level are:

$$\frac{\partial W/\partial O_i \cdot \partial O_i/\partial I_j}{P_j} = \frac{\partial W/\partial O_k \cdot \partial O_k/\partial I_L}{P_L}$$

for all i, k such that j and L are actually used in the production of i and k respectively.[13]

The second order conditions for a welfare maximum require alternating signs for the determinants of the principal minors of the relevant bordered Hessian.[14]

If no constraints other than the technical constraints are imposed and the decision maker is a successful maximizer, it is necessarily the case that

$$\partial TC/\partial O_i \geqq 0$$

at the welfare maximum. Since it is known that constraints are imposed on departments from outside on outputs and on inputs, these conditions need not hold in fact. If constraints were placed such that they did not interfere with the attainment of welfare maximum, then these conditions would hold. That is, if constraints do not constrain, then the welfare maximum may be achieved.[15]

The Hypotheses

The cost function developed above will be estimated in Chapter III and the estimated function will be used in order to test the hypotheses developed below.

Two sets of hypotheses will be tested: 1) the assumptions implied by present cost accounting techniques and 2) the effectiveness of constraints and departmental decision makers in maximizing welfare.

Assumptions of Present Techniques

The point was made in the introduction to this thesis that the following assumptions were implied by the cost accounting techniques in common use to estimate instructional costs:

1) There are no interactions among levels of instructional output--all outputs are independent.

2) There are no economies or diseconomies of scale in production.

3) Negative average variable costs are not possible in any range of output by definition.

These three assumptions will be tested after the instructional cost function is estimated.

Effectiveness of Constraints and Decision Makers

Since all cost estimates produced for decision making agencies have shown that costs increase with student level and have shown all costs to be positive, it is implied that, at present output levels, all outputs are valued since they continue to be produced and it is also implied that outputs are valued more highly at the margin as student level increases. If constraints placed upon departments are not effective in preventing the reaching of a welfare maximum and if departmental decision makers do not make errors in the allocation process, then the above model implies that, at output levels encountered, marginal costs of instruction must be positive at all levels of output and that marginal costs must increase with student level. In testing these two hypotheses, the criteria really test the degree to which error has or has not been made--errors at the departmental level in allocating resources or at the higher levels in restricting outputs.

By examining the constraints on a given department, it may be possible to identify specific errors in the constraints applied, but this will not be done in this thesis. By looking at constrained outputs and finding that marginal costs are in some instances negative or by finding that marginal costs are not increasing where decision makers believe them to be increasing with student level, the constraints and the decision makers can be found lacking in that welfare has not been maximized--welfare as the decision makers view welfare has not been maximized. The following two hypotheses will then be examined empirically to ascertain the effectiveness of the constraints and the quality of the decision making:

4) Marginal costs are nowhere negative for constrained outputs.

5) Marginal costs increase as student level increases.

While there is reason to believe that interactions among levels of instruction are likely (hypothesis 1) and while economies or diseconomies of scale in instruction also seem likely to occur (economies of scale seem particularly likely to occur at the lower levels of production--at the undergraduate level) (hypothesis 2) and while negative average costs are possible when interactions occur (hypothesis 3), the model and welfare maximization imply that all marginal costs will be positive and that marginal costs increase with student level when taken in conjunction with past data and past decisions.

The Market for Student Labor

A significant portion of the argument above turns on the use of students as inputs into the instructional process; and therefore, it seems proper to examine the nature of the market for student labor. The demand side should be quite straight forward with the quantity demanded a function of price, ability, government subsidies, alternate sources of the same expertise, and so on. The supply side should be relatively easily understood also.

The student's utility function is:

$$U = U\ (I,\ Y,\ C,\ E,\ O)$$

where I is a vector of factors associated with instruction and certification offered by a given institution such as courses offered and perceived quality, Y is a vector of income opportunities associated with employment, C is a vector of costs incurred in the educational and work process, E is a vector of extracurricular factors associated with an institution and its location, and O is a vector of all other factors.

It is clear that a student's willingness to work for his institution, once the institution is chosen, depends upon other opportunities for work available to him. *Ceteris paribus*, most students will prefer working for their institution for the following reasons: a) travel time is minimized, b) work can more easily be scheduled between classes, c) work can more often be done with friends and peers, d) work provides contact with faculty and administrators and other students and is often school related.

The graduate student in particular may prefer working as a graduate assistant in that a) research and teaching experience can be gained and b) research topics can be developed and c) familiarity with the academic environment can be developed. These factors tend to reduce the salary necessary to attract student labor below the salary necessary in the non-university marketplace. Thus it should be no surprise if highly talented students with strong backgrounds in particular fields are willing to work at what appear to be less than equilibrium wages.

If institutions recognize the full productivity of graduate students, in particular, the market should produce a situation where marginal product of graduate students divided by their price should equal marginal product divided by price for all other inputs. Competition among institutions for assistants should raise the wage to equilibrium. If certain institutions are prevented from competing for these students; however, even if those institutions in the market pay the equilibrium wage, it would be expected that the prevailing student wage rate would rise if all institutions were allowed to enter the market and compete for graduate students and for graduate assistants. This does not mean that the wage would necessarily rise to match wages paid outside the academic area, but certainly the wage would be expected to rise for those categories of students where competition has been limited. Universities may actually be willing to pay higher wages than external agents in some instances because of lack of mobility of the specialized resources needed.

The Market for Faculty Input

It is important to realize that student employment is not the only argument for the existence of inter-relationships between and among instructional levels. Many factors enter into a faculty member's utility function and among these are: the quality of student taught, the opportunity for student assistance of high quality, and prestige as well as the opportunity to interact with high quality faculty members and to utilize sophisticated research techniques. These factors indicate that faculty may prefer to work at an institution with higher level programs in a discipline, all other factors equal. This supply side effect is not necessary; however, since there are other factors which may reduce interest in working at institutions with more advanced programs.

On the demand side, institutions with graduate programs may be willing to pay more than institutions without graduate programs for a given faculty member since the probability of research grant receipt is higher at the graduate institution given its typically greater prestige and probable superior research support activities and facilities. The receipt of a research grant can effectively reduce the cost of instruction since the overhead funds may more than cover actual expenses incurred while, at least on occasion, it is also the case that instructional activity is engaged in even when salary is being fully paid from the grant.

It may well be that faculty members are, in effect, more productive for institutions with graduate programs than for institutions without programs at a given level. Whether savings are realized by paying lower nominal wages due to more attractive working environment or paying lower real wages (while the faculty member receives higher real wages), there is a possibility that the presence of a program at a given level, more probably at the graduate level than elsewhere, may actually lower costs by affecting the cost of faculty inputs.

The Outputs

The outputs with which this thesis deals quantitatively are strictly instructional but dummy variables will be used to account in a qualitative sense for other products of academic departments including research and public service. The instructional products, as noted earlier, will be classified as lower division (freshmen and sophomores), upper division (juniors and seniors), masters level (this category includes graduate professional course work), and doctoral. Research and public service were excluded as quantitative variables because of lack of consistent, adequate, or reliable data. This lack of data is clearly a problem; however, it is argued below that it is not crucial for the following reasons:

> A. At least part of the incentive for undertaking and completing research and public service is future monetary and non-monetary compensation both inside and outside the university. This will have a tendency to lower the current cost to the university of research done by the faculty. The same cannot be said of teaching activity generally.
>
> B. In compiling the data used here, The Michigan Council of State College Presidents made every effort to exclude expenditures for activities other than teaching wherever possible. Some research and public service activities are separately budgeted and those expenditures were definitely excluded from the expenditure data used here. It is clear, however, that some research and public service expenditures may be included and should be accounted for.
>
> C. It is not clear that instruction, within the instructional budget at least, is always done at the expense of research or public service activities. In order to get a faculty member to reduce research output as a result of increased instructional load (although that is unlikely to be a goal), the marginal utility of research effort must be reduced relative to the marginal utility of instructional activity. Since much of the incentive to perform research comes from outside the university and since instructional effort per student and per course can vary significantly, increased instructional responsibility may not significantly change research output in the short run or in the long run. The additional students may simply have to spread the faculty member's instructional time a little more thinly among themselves.

> An institution can move from a research orientation to a teaching orientation by changing its faculty members, but it is not clear that even this move will produce more instruction since there is a quality dimension to instruction as well as a strict quantity dimension. Given a particular student body type and the instructional needs implied, there is a significant chance that teaching load may be determined largely on the basis of decisions measuring opportunity cost in terms of instruction and instructional quality rather than in terms of other university outputs.

These arguments do not indicate that research is necessarily a free good in terms of instruction as measured for this research, but there is clearly the possibility that research is less expensive in terms of instruction than some may believe.[16] Since the factors which have not been measured which determine costs will be allowed to enter the analysis in terms of a qualitative variable, and since there are no consistent and reliable data available, the problem of dealing with the costs of research and public service activities quantitatively will need to await future research.

The dummy variables will represent the difference, on the average, in costs between each institution and Michigan State University, the base institution. This will compensate for the lack of data on other outputs to some degree. The efficiency with which this is done will depend upon the homogeniety of the departments within a given discipline and institution. If there is complete homogeniety with respect to other outputs and costs, then the dummy variable will compensate perfectly for the lack of data. The more heterogeneous the departments in a given institution-discipline, the less well the dummy variable will operate. Given the arguments above which show that the cost of other outputs can be less than might be expected and reasonable homogeneity within the relevant departmental groupings, the use of dummy variables in this case will provide the desired results.

The Output Measure

An ideal unit for measuring instructional output for use in the production function would include: 1) the number of students served, 2) the gain in educational attainment measured from the beginning of the educational experience to the end, 3) the time retention which would measure the retention of material covered and the expansion of knowledge after the formal educational process for which that process was responsible, 4) a difficulty dimension to measure and compensate for the differential abilities of individuals to learn and for the time spent by the student in mastering the material, and 5) a value dimension to standardize the above measures with respect to the value to the learner or to the society of the material learned.

Although it does not meet the above criteria for an ideal measure of educational output, the best available measure of instructional output is the student credit hour which is obtained by multiplying the number of students in a class by the number of credit hours of the class. A class with thirty students which carried four credit hours would produce 120 student credit hours (30 x 4).

This measure does account for the number of students served and it at least partially accounts for the quantity of material covered if it is assumed that more credit hours usually imply more material within a given discipline at a given student level. It does not account for individual differences in student ability nor does it account for time retention. The student credit hour is, however, the currency of academia and therefore does have some consistency if converted to the same measurement system (semester, quarter, etc.). In addition, this is the only measure used in the available data.

Other candidates for a measure would include the degree and various measures of attainment gained from a testing program. The degree is a difficult measure since requirements vary widely. And costs are difficult to associate with a given program since many students transfer among institutions and follow widely differing time paths toward the degree.

Test results would be appropriate if properly and consistently applied and if the results could be attached to a particular course, or to the university in any way, and therefore to a particular expenditure. All techniques presently available to attach university costs to a given university experience have inherent in them the problems discussed in Chapter I with reference to present cost estimation procedures. In addition, test results of the types needed are not available.

While the student credit hour is not ideal as a measure of output, it was the measure accepted by the Michigan Council of State College Presidents as well as many others and is probably the best measure available in most senses.

The Classification of Departments into Disciplines

This research will produce results for six disciplines: Business Administration, Education, Engineering, Humanities, Natural Sciences, and Social Sciences. These are fairly standard classifications although the criteria for membership are not well defined. In developing the classification of departments by discipline, the following were taken into consideration to some degree: 1) consistency in teaching techniques typically used and in class size, 2) typical collegiate groupings at larger universities, 3) other classification systems which have been developed for use in classifying departments for cost study purposes[17], and 4) the distribution of the data in the various categories as available from the Michigan Council of College Presidents. Where possible, standard classification systems were adhered to, and when a given department did not fit well into one of the six categories used, in the opinion of the author, the data were not included in the study. All classification decisions were made before regressions were run and none were made after the fact. The entire classification of department titles as they were used in this research is found in table 1. There is certainly room for debate on the classification and some decisions between classifications were not easily made, but on the whole it is felt that the classification system is reasonable.

Conclusion and Summary

This chapter presents a theory of the way that resources are distributed among the various instructional outputs of a system of higher education as viewed from the departmental level. Given a welfare function, production functions, and the constraints under which the decision makers must operate, this model predicts how much and what types of instructional output will be produced. It could also be extended to other outputs

TABLE 1

ACADEMIC DEPARTMENTS BY NAME AND BY DISCIPLINE

Name

Accounting - Business Administration
Aerospace Engineering - Engineering
Afro-American Studies - Humanities
Agricultural Engineering - Engineering
American Thought and Language - Humanities
Anthropology - Social Sciences
Art - Humanities
Art Education - Education
Astronomy - Natural Sciences
Biochemistry - Natural Sciences
Biophysics - Natural Sciences
Biology - Natural Sciences
Botany and Plant Pathology - Natural Sciences
Business - Business
Business Education - Education
Chemical Engineering - Engineering
Chemistry - Natural Sciences
Civil and Sanitary Engineering - Engineering
Classical Studies - Humanities
Computer Science - Engineering
Criminal Justice - Social Science
Distributive Education - Education
Economics - Social Sciences
Education Administration - Education
Educational Leadership - Education
Educational Psychology - Education
Educational Sociology - Education
Electrical Engineering - Engineering
Elementary Education - Education
Engineering - Engineering
Engineering Mechanics - Engineering
Engineering Studies - Engineering
Engineering Technology - Engineering
English - Humanities
Entomology - Natural Sciences
Evaluation and Research - Education
Family Life Education - Education
Far Eastern Languages and Literature - Humanities
Foreign Languages - Humanities
French - Humanities
Geography - Social Sciences
Geology - Natural Sciences
German - Humanities
Great Issues - Humanities
Greek and Latin - Humanities
Guidance and Counseling - Education
Higher Education - Education

TABLE 1 (Continued)

History - Humanities
History and Philosophy - Humanities
History of Art - Humanities
Hotel Management - Business
Humanistic Studies - Humanities
Humanities - Humanities
Industrial Education - Education
Instructional Technology - Education
Industrial Engineering - Engineering
Insurance - Business
Labor and Industrial Relations - Social Sciences
Linguistics - Humanities
Literature - Humanities
Management - Business
Marketing - Business
Mathematics - Natural Sciences
Mechanical Engineering - Engineering
Metallurgy - Engineering
Meteorology - Natural Sciences
Mining Engineering - Engineering
Music - Humanities
Music Education - Education
Natural Science - Natural Sciences
Near Eastern Languages - Humanities
Nuclear Engineering - Engineering
Philosophy - Humanities
Physics - Natural Sciences
Political Science - Social Sciences
Psychology - Social Sciences
Reading - Education
Religion - Humanities
Romance Languages - Humanities
Russian - Humanities
School of Business Administration - Business
School of Fine Arts - Humanities
Science Education - Education
Secondary Education - Education
Secondary English, Speech and Foreign Languages - Education
Secondary Mathematics - Education
Secondary Social Sciences - Education
Slavic Languages - Humanities
Social Sciences - Social Sciences
Social Work - Social Sciences
Sociology - Social Sciences
Spanish - Humanities
Special Education - Education
Statistics - Natural Sciences
Teacher Education - Education
Theatre - Humanities
Urban Planning - Social Sciences
Zoology - Natural Sciences

TABLE 1 (Continued)

Discipline

Business Administration

Accounting
Business
Hotel Management
Insurance
Management
Marketing
School of Business Administration

Education

Art Education
Business Education
Distributive Education
Education Administration
Educational Leadership
Educational Psychology
Educational Sociology
Elementary Education
Evaluation and Research
Family Life Education
Guidance and Counseling
Higher Education
Industrial Education
Instructional Technology
Music Education
Reading
Science Education
Secondary Education
Secondary English, Speech and Foreign Languages
Secondary Mathematics
Secondary Social Sciences
Special Education
Teacher Education

TABLE 1 (Continued)

Discipline
Engineering
Aerospace Engineering
Agricultural Engineering
Chemical Engineering
Civil and Sanitary Engineering
Computer Science
Electrical Engineering
Engineering
Engineering Mechanics
Engineering Studies
Engineering Technology
Industrial Engineering
Mechanical Engineering
Metallurgy
Mining Engineering
Nuclear Engineering
Humanities
Afro-American Studies
American Thought and Language
Art
Classical Studies
English
Far Eastern Languages and Literature
Foreign Languages
French
German
Great Issues
Greek and Latin
History
History and Philosophy
History of Art
Humanistic Studies
Humanities
Linguistics
Literature
Music
Near Eastern Languages
Philosophy
Religion
Romance Languages
Russian
School of Fine Arts

TABLE 1 (Continued)

Discipline
Humanities (Continued)
Slavic Languages
Spanish
Theatre
Natural Sciences
Astronomy
Biochemistry
Biophysics
Biology
Botany and Plant Pathology
Chemistry
Entomology
Geology
Mathematics
Meteorology
Natural Sciences
Physics
Statistics
Zoology
Social Sciences
Anthropology
Criminal Justice
Economics
Geography
Labor and Industrial Relations
Political Science
Psychology
Social Sciences
Social Work
Sociology
Urban Planning

of higher education without significant modification.

In addition to developing the model, the following testable hypotheses have been developed:

(1) There are interactions among levels of instructional output with respect to costs. (p. 20)

(2) There are economies of scale and/or diseconomies of scale in the production of instruction. (p. 20)

(3) There are negative average variable costs within the range of outputs which actually occur in educational institutions. (p. 20)

(4) Marginal costs are negative in some instances within the range of actual outputs. (p. 22)

(5) Marginal costs often do not increase as student level increases. (p. 22)

The above are not the forms in which these hypotheses were earlier introduced, but they are in the form in which they will be tested.

These hypotheses will be tested through the estimation of the cost function:

$$TC = TC\ (0_1,\ 0_2,\ 0_3,\ 0_4,\ 0_5,\ P^*)$$

where 0_1 through 0_4 are the instructional outputs, 0_5 represents all other outputs, and P* is the price level.

This total cost function for the departmental level was derived from the model developed in the chapter:

$$W = W\ (O_1,\ O_2,\ O_3,\ O_4,\ O_5)$$

$$O_1 = O_1\ (I_{1_1}, \ldots, I_{q_1}, I_{O_{1_1}}, \ldots, I_{O_{5_1}})$$

$$O_5 = O_5\ (I_{1_5}, \ldots, I_{q_5}, I_{O_{1_5}}, \ldots, I_{O_{5_5}})$$

$$B \geqq \sum_{i=1}^{q} P_i I_i + \sum_{j=1}^{5} I_{O_j} P_{j+q}$$

$$I_i = \sum_{k=1}^{5} I_{i_k} \quad \text{and} \quad I_{O_j} = \sum_{k=1}^{5} I_{O_{j_k}}$$

$$O_k \leq C_k\ , \quad k = 1,\ 2,\ 3,\ 4,\ 5$$

$$(Q_i) \cdot (O_i) \geqq \sum_{j=1}^{5} I_{O_{i_j}}\ , \quad i = 1,\ 2,\ 3,\ 4,\ 5$$

In Chapter III, the above hypotheses will be tested after the departmental instructional cost function is estimated.

Footnotes Chapter II

9. Jan Tinbergen, <u>On the Theory of Economic Policy</u>, (Amsterdam: North-Holland Publishing Company, 1952).

10. This may be more accurately expressed as "The existence of certain outputs of higher education imply the existence of certain potential inputs which may not be available unless the first set of generating outputs is produced by a given university." O_1 and I_{O_1} will be measured in different units, educational output at the masters level in student credit hours and masters level graduate assistance in hours worked.

11. Marginal cost should also be included with prices and wages to cover the case where prices are not fixed by an external market.

12. It may also be considered to be simplified in that the list of characteristics purchased when a faculty member is hired is long. Price data would be required for each faculty member or for each faculty type, given an adequate classification system, or for each faculty characteristic purchased. Neither of these is available so that this simplifying assumption is required.

13. This is strictly from the departmental point of view. Equalization between departments and between departmental and non-departmental outputs is the responsibility of non-departmental decision makers.

14. James H. Henderson and Richard E. Quandt, Microeconomic Theory: A Mathematical Approach, (New York: McGraw Hill, 1958) page 271.

15. Here it is assumed that constraints have been placed under the assumption that the departmental decision makers are not capable of maximizing welfare without such guidance because of lack of information or a differing perception of the welfare function.

16. There is even the possibility that the opportunity to do research may reduce costs of instruction in addition to producing research since performing research is an investment in human capital for the faculty member, research yields some pleasure in and of itself for some, and the research process may provide some non-paid instruction where a faculty member is being paid from a research grant. In other words some faculty members may be willing to work for lower nominal wages--thus saving the institution money--while actually receiving higher real wages with part of the payment in the form of opportunity to perform additional research. This possibility seems somewhat remote; however, it should be considered.

17. There are several such systems, none of which met the needs of this research.

CHAPTER III

In this chapter the instructional cost function as derived from the model in Chapter II will be estimated and the hypotheses developed will be tested.

Estimation of the Instructional Cost Function

Departmental data obtained from the Michigan Council of State College Presidents[18] covering departments in thirteen institutions in the Michigan state system of higher education over a period of nine years will now be used to estimate the instructional cost function in higher education at the department level. The specific function which will be estimated will be of the form:

$$TC = \sum_{i=1}^{4}(B_iX_i + B_{i+4}X_i^2 + B_{i+8}X_i^3) + \sum_{i=1}^{12}B_{i+12}D_i + \sum_{i=2}^{4}B_{i+24}X_1X_i + \sum_{i=3}^{4}B_{i+27}X_2X_i + B_{30}X_3X_4 + B_{31}T + B_{32} + \varepsilon$$

where X_1 is lower division (freshman and sophomore) instructional output measured in semester credit hours, X_2 is upper division (junior and senior) output, X_3 is masters level (masters and graduate professional) instructional output, X_4 is doctoral level instructional output, D_i are twelve institutional dummy variables, T is the time trend variable representing the year number from 1 through 9, B_{32} is the constant, and ε represents the discrepancy between the planned expenditure-output and the actual expenditure-output relation and the combined effect on expenditures of various noise factors.

Linear, Square and Cubic Terms

This form of the function containing linear, square, and cubic terms for each variable, allows testing of hypotheses regarding the existence of linear relationships, economies of scale and/or diseconomies of scale. With these factors included, Hypothesis (2) as listed at the end of Chapter II can be tested:

> There are economies of scale and/or diseconomies of scale in the production of instruction.

It is expected *a priori* that such (dis)economies may well exist, and if they do exist, that they will disappear as output increases and thus affect only lower output levels. After a certain level, it is expected that the cost-output relation will essentially become linear and marginal (dis)-economies of scale initially encountered will disappear. Marginal economies of scale at the departmental level will be expected to disappear at some point after all classes, even the specialized ones, are filled to their maximum efficient size. Marginal diseconomies of scale are not expected to be encountered at all at the undergraduate levels of instruction since it is expected that these, if they exist, will be caused by the higher price implied by faculty who are recruited to teach at the graduate level but also teach at the undergraduate level. With small graduate level programs, such faculty members may be inefficiently used as undergraduate teachers in the sense that they may teach undergraduate courses where a less expensive faculty member would have been hired to teach these courses if the institution did not offer a graduate program. With a small doctoral level program, doctoral level faculty may be inefficiently used in the same sense in teaching masters level courses. In both cases the introduction of a small higher level program may be initially more expensive per unit than it is when it is larger and faculty can specialize at the graduate level where appropriate. This potential inefficiency in the use of faculty members will have its largest net effect in disciplines where there are larger salary discrepancies between faculty that would normally be considered qualified to teach at the graduate level and faculty that would normally be considered qualified to teach only at the undergraduate level, where use of graduate assistants is not sufficient to compensate for this inefficiency, and where more specialties in graduate programs are usually necessary in order to attract students (more specialized faculty members may well imply more faculty teaching at both the graduate and undergraduate level where this would not be appropriate or necessary if the program were large enough to allow faculty to specialize at given student levels as well as in particular areas of their discipline). It is expected that most undergraduate programs will exhibit non-linear relationships showing marginal economies of scale at low levels of output but will approach a linear cost relationship as output increases. Expectations for graduate programs are not well defined since the cost relationship is expected to be more complicated at the graduate level although any initial (dis)economies will be expected to disappear at the margin.

Since it is expected that such (dis)economies of scale will exist and will also tend to disappear, the inclusion of both the square and cubic terms can be used to approximate the true relation as well as providing possible tests for the existence of such (dis)economies of scale at the margin. The table below shows the way in which marginal (dis)economies of scale will exhibit their existence if the coefficients of the cubic terms are assumed to be small, not insignificant, relative to the coefficients of the square terms.

Sign of square term

sign of cubic term		+	-
	+	GROWING DISECON-OMIES OF SCALE	INITIAL ECONOMIES OF SCALE
	-	INITIAL DISECON-OMIES OF SCALE	GROWING ECONOMIES OF SCALE

Figure 1
Coefficient Signs and (Dis)Economies of Scale

Given the expectations argued for above and Figure 1, it will be expected that initial economies of scale will be encountered for undergraduate outputs. If any diseconomies of scale are encountered, these will be seen at the graduate level although economies of scale are also possible. It will therefore be expected that the signs of the square terms, if significant, will be negative at the undergraduate level and will have indeterminate signs at the graduate level. Since it is expected that all marginal (dis)economies of scale will disappear at larger outputs, it will also be expected that the signs of the cubic terms, if significant, will differ from the signs of the square terms.

The Dummy Variables

Each institution in the study except Michigan State University is represented by a dummy variable which is intended to account for all institutional differences other than level of output. These differences are expected to include: differences in the accounting procedures and definitions of output levels (these data were gathered so that the differences would be minimized; however, in such complex areas, it is unlikely that such differences can be eliminated entirely), quality of programs, differences in institutional effort in non-instructional areas such as research and public service which have not been separately budgeted, differences in the market prices of productive resources in the widely varying parts of the state in which these institutions are located, differences in student clientele, and all other differences. The use of qualitative variables to account for these differences was required by the lack of reliable and consistent data on the various component differences and the large number of such differences which may occur. It is expected that differences will be encountered among institutions and there is reason to believe that, where significant, these differences are likely to be negative for all institutions except the University of Michigan where the difference is likely to be positive when one is present. This relationship is not implied by the model and is expected to vary from discipline to discipline. These expectations are based largely on expected differences in quality of inputs and differences in effort in non-instructional areas--it is expected that in most instances the University of Michigan will produce the largest proportion of non-instructional output and the other institutions will produce a smaller proportion of non-instructional output than Michigan State University, the base institution.

The Interaction Terms

As argued above in Chapter II, it is expected that there will be interactions among the student levels of production which will affect costs. These are accounted for in the model by the inclusion of interaction terms in the cost function to be estimated and the significance of these terms will be used to test the hypothesis that such interactions do exist. The sign or significance of these terms cannot be derived from the model since in each case there are potential causes for reduced costs and potential causes for increased costs. These again are expected to vary among disciplines. The interaction terms take the form: B·(Lower Division SCH) · (Upper Division SCH). Inclusion of such terms, and there are six possible combinations, allows the first partial derivative of the cost function with respect to one of the outputs, the marginal cost of the output, to be a function of other output levels. Since this is likely to be the case, there is strong reason for their inclusion *a priori*.

The Time Trend

The time trend is present to correct for inflation in the costs of inputs over the nine year period covered by the data. It is expected that the time trend coefficient will be positive and significant for all disciplines. The growth in enrollments during this period was not accompanied by equivalent growth in the number of qualified faculty members which resulted in inflation in the prices of inputs to higher education somewhat in excess of the general inflation rate.

The Constant Term

The constant term is included in the relation in order to represent any fixed costs, to show the mean effect of any omitted variables, and in order to allow for interpretation of standard statistics such as R^2.

The Technique

The above cost function is estimated separately for each of the six disciplines: Business Administration, Education, Engineering, Humanities, Natural Sciences, and Social Sciences, using weighted least squares with the square root of total output as the weight, with total departmental instructional expenditure as the dependent variable measured in dollars, and with outputs as the right hand variables measured in student credit hours. The standard assumptions are made regarding the distribution of error terms after the application of the weighted least squares procedure.

The Data

The data provided by the Michigan Council of State College Presidents cover departments at thirteen institutions: Central Michigan University, Eastern Michigan University, Ferris State College, Grand Valley State College, Lake Superior State College, Michigan State University, Michigan Technological University, Northern Michigan University, Oakland University, Saginaw Valley State College, The University of Michigan, Wayne State University, and Western Michigan University. They included the years for which the *Unit Cost Study* was done: 1962-63, 1963-64, 1964-65, 1966-67, 1968-69, and 1970-71. Total departmental expenditures for instruction and the quantity of output is provided in semester student credit hours for each of the four student levels: lower division, upper division, masters, and doctoral.

The Results

The results of the weighted least squares regressions are found in Tables 2, 4, 6, 8, 10, and 12 for the six disciplines. The dependent variable is in dollars. The first column lists the coefficient estimate, the second column lists the standard error and the third column shows t-values. Two tailed tests are used throughout and significance is defined at the ten percent level although other levels of significance are identified in the tables. Two tailed tests are used even though there are reasons to expect certain signs since in each case the relationships are complicated enough that either sign may result with the exception of the time trend variable where the positive value is definitely predicted but where two tailed tests vs. one-tailed tests does not arise.[19] In addition to t-tests on each coefficient individually, F-tests are presented at the end of each table showing the significance of five groupings of the variables: all linear variables, all square variables, all cubic variables, all interaction terms, and all institutional dummy variables.

Data characteristics for each discipline are then presented in Tables 3, 5, 7, 9, 11, and 13. Each of these tables is found directly following the relevant weighted least squares results by discipline. For each variable, the mean and standard deviation are shown.

After each table of data characteristics, four figures are found numbered Figure 2 through 5, Figure 6 through 9, Figure 10 through 13, etc. These show the average variable cost and marginal cost functions graphically for each output as they would appear with all variables in and evaluated at mean output for the three other student levels. These exhibit all the possible relationships between these relations and give a better idea of the meaning of the parameter values.

Business Administration Departments

In Table 2, the following variables are shown to be significant and increasing total costs for Business Administration departments--all measures are in dollars per relevant unit: Linear Upper Division ($42.55), Linear Doctoral ($1136), Doctoral Cubed ($.1842E-02), Time Dimension(25650), Lower Division times Masters ($.9813E-02), Upper Division times Masters ($.1131E-01), and University of Michigan ($.1066E07). The following variables are significant and reduce total cost--again in dollars per relevant unit: Linear Masters (-$94.86), Upper Division Squared (-$.5604E-02), Doctoral Squared (-$2.442), Lower Division times Doctoral (-$.9925E-01), Masters times Doctoral (-$.6834-01), and all institutional dummy variables with the exception of Wayne State University. Each of the five sets of grouped variables is significant using an F-test. And it should be noted that all coefficients of square terms are negative while all cubic terms are positive.

Wayne State University is apparently more similar to Michigan State in the Business Administration area than the other institutions in the study and just as expected, those economies of scale found significant (significant negative coefficients on the square variable) are eventually swamped by positive coefficients on the matching cubic variable. In fact, all student levels

TABLE 2

COST FUNCTION ESTIMATES--BUSINESS ADMINISTRATION

Variable	Coefficient Estimate	Standard Error	t-value
Lower Division (LD)	19.84	16.17	1.227
LD^2	-.1715E-02	.2808E-02	-.6107
LD^3	.7808E-07	.9268E-07	.8425
Upper Division (UD)	42.55*	17.55	2.425*
UD^2	-.5604E-02*	.2792E-02	-2.007*
UD^3	.1858E-06	.1323E-06	1.404
Masters (M)	-94.86**	30.77	-3.082**
M^2	-.3578E-02	.6218E-02	-.5754
M^3	.7850E-07	.2303E-06	.3409
Doctoral (D)	1136**	300.0	3.789**
D^2	-2.442**	.7459	-3.274**
D^3	.1842E-02**	.4252E-03	4.438**
LD x UD	.6739E-04	.1709E-02	.3942E-01
LD x M	.9813E-02*	.3783E-02	2.594*
LD x D	-.9925E-01**	.3074E-01	-3.229**
UD x M	.1131E-01**	.4038E-02	2.801**
UD x D	.3796E-01	.3292E-01	1.153
M x D	-.6834E-01**	.2343E-01	-2.916**

* Significant at ten percent level

** 1%

TABLE 2 (Continued)

Variable	Coefficient Estimate	Standard Error	t-value
Time	25650.**	2620.	9.790**
Central Michigan University	-75200.*	42270.	-1.779*
Eastern Michigan University	-68250.*	32590.	-2.094*
Ferris State College	-106400**	32340.	-3.291**
Grand Valley State College	-189900.**	65060.	-2.918**
Lake Superior State College	-150100.*	79580.	-1.886*
Michigan Technological University	-81820.*	40520.	-2.019*
Northern Michigan University	-115700.**	37930.	-3.050**
Oakland University	-86540.*	49450.	-1.750*
Saginaw Valley State College	-179400.*	79900.	-2.245*
University of Michigan	1066000.**	165500.	6.446**
Wayne State University	14190.	33160	.4278
Western Michigan University	-55500.*	30780.	1.803*
Constant	-25560.	41800.	-.6115

* Significant at the ten percent level

** 1%

TABLE 2 (Continued)

Number of observations:	158
Degrees of Freedom:	127
R^2	.97511
$\overline{R}^2$	.96923
F-tests for Groupings of Variables	
Linear Variables	9.619**
Square Variables	4.873**
Cubic Variables	5.671**
Interactions	4.661**
Institutional Variables	2.603**

* Significant at the ten percent level

** 1%

TABLE 3

DATA CHARACTERISTICS--BUSINESS ADMINISTRATION

Variable	Mean	Standard Deviation
Lower Division (LD)	3288	2813
LD^2	.1867E+08	.4920E+08
LD^3	.1833E+08	.1002E+13
Upper Division (UD)	6526	3282
UD^2	.5329E+08	.4597E+08
UD^3	.4930E+12	.5787E+12
Masters (M)	2206	3897
M^2	.1996E+08	.6624E+08
M^3	.2860E+12	.1210E+13
Doctoral (D)	170	344
D^2	146600	388700
D^3	.1502E+09	.5078E+09
LD x UD	.2353E+08	.3061E+08
LD x M	.4689E+07	.6843E+07
LD x D	420830	.1045E+07
UD x M	.2083E+08	.4249E+08
UD x D	.1751E+07	.3757E+07
M x D	.1505E+07	.4812E+07

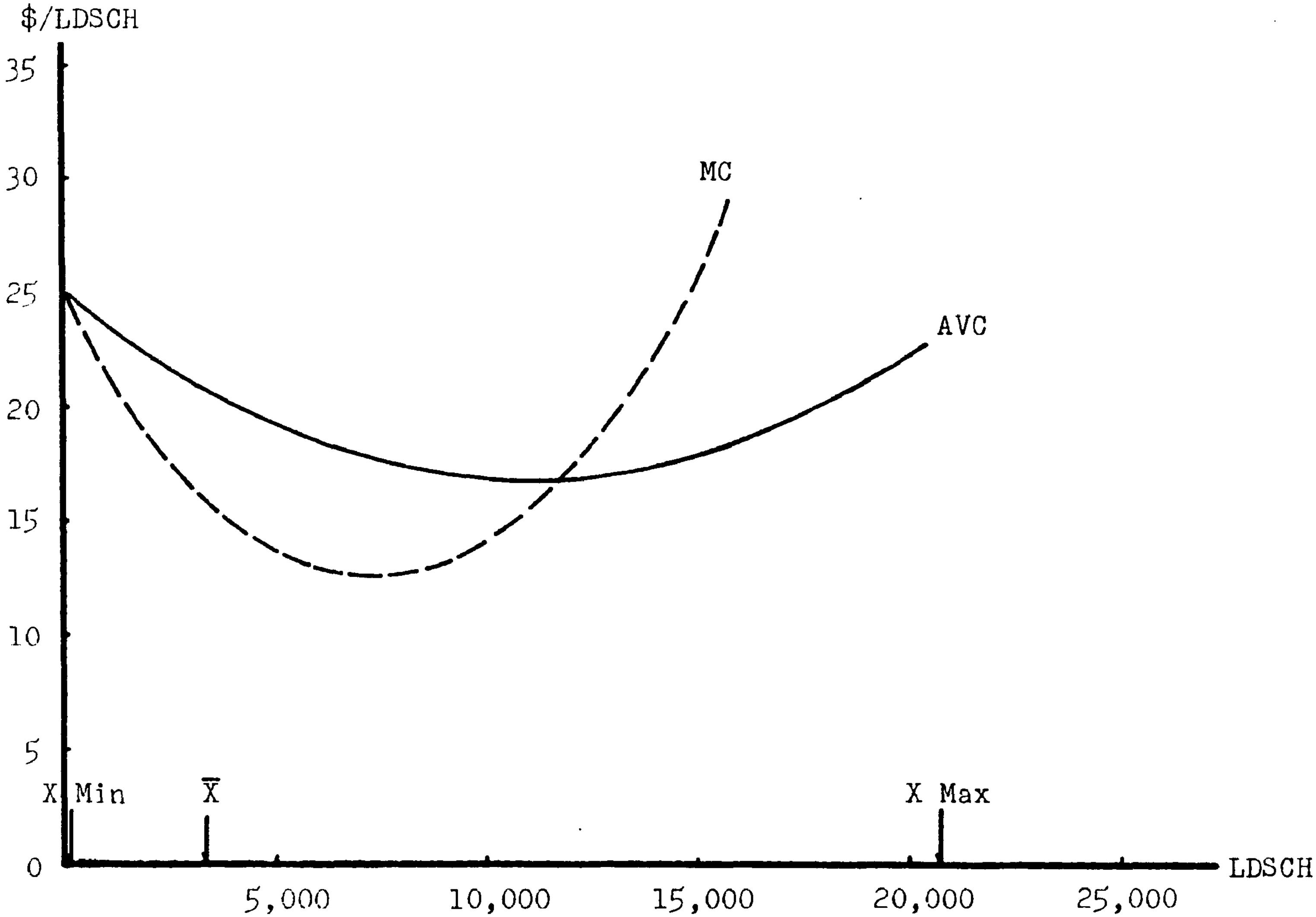

FIGURE 2

BUSINESS ADMINISTRATION LOWER DIVISION

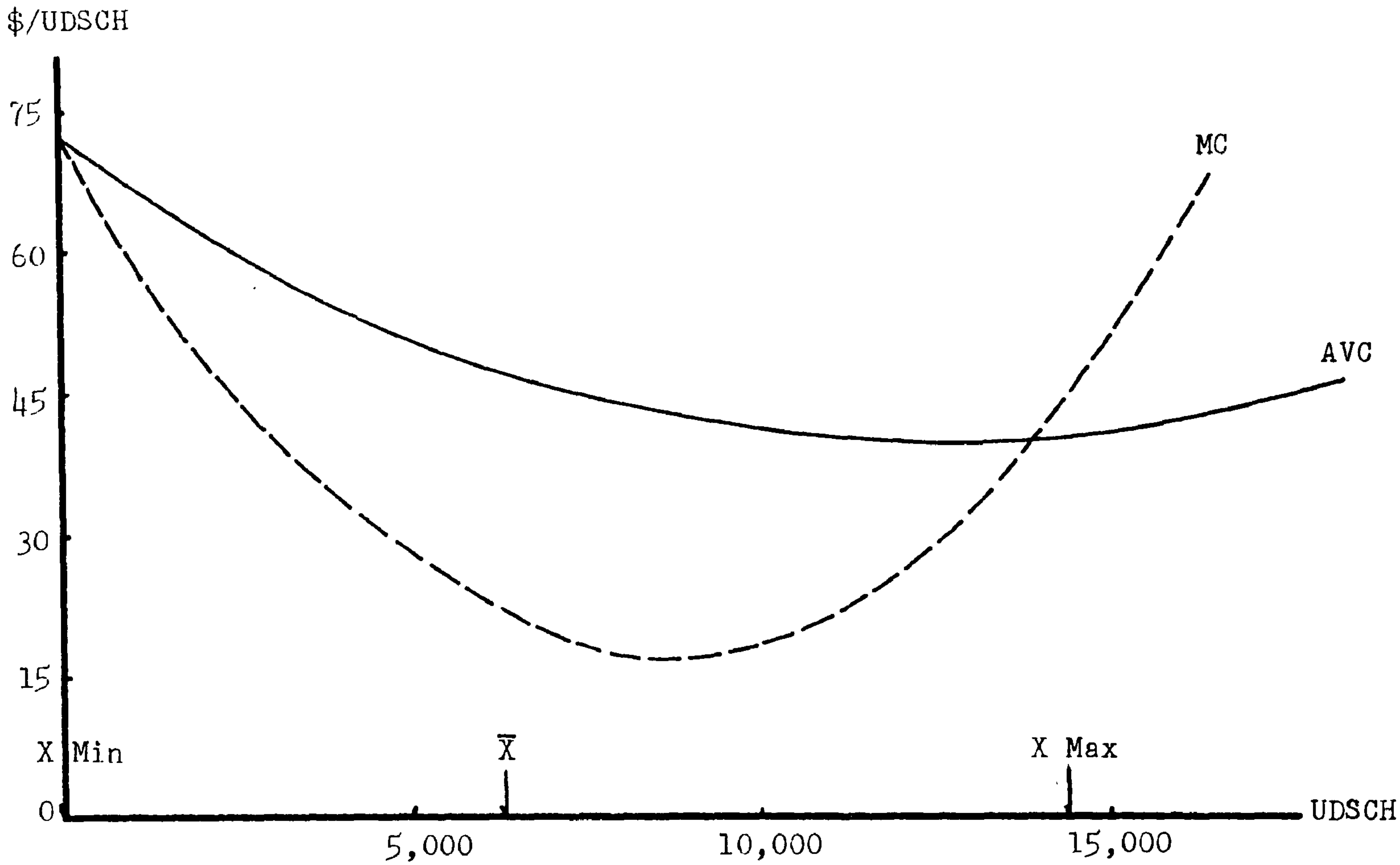

FIGURE 3

BUSINESS ADMINISTRATION UPPER DIVISION

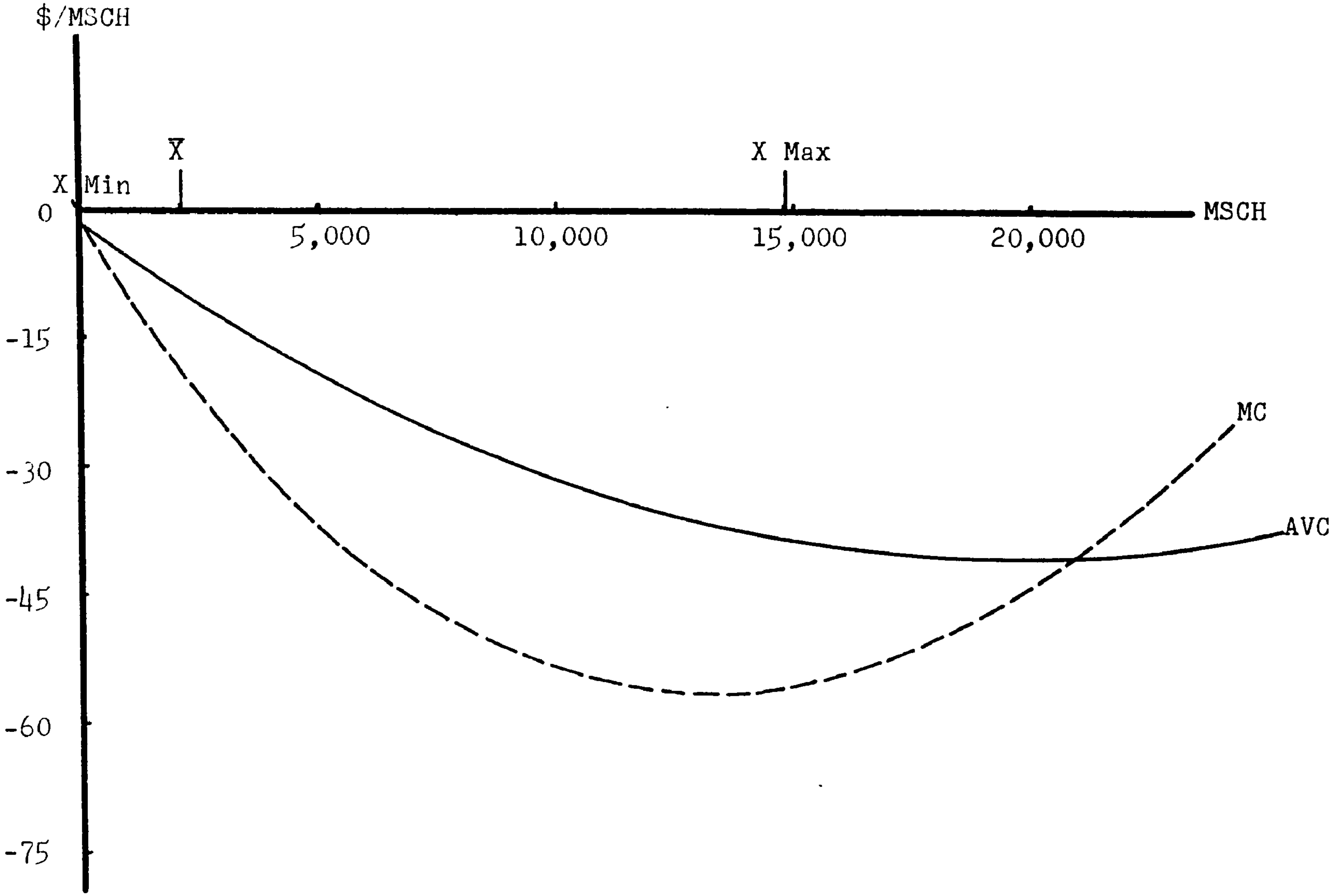

FIGURE 4

BUSINESS ADMINISTRATION MASTERS

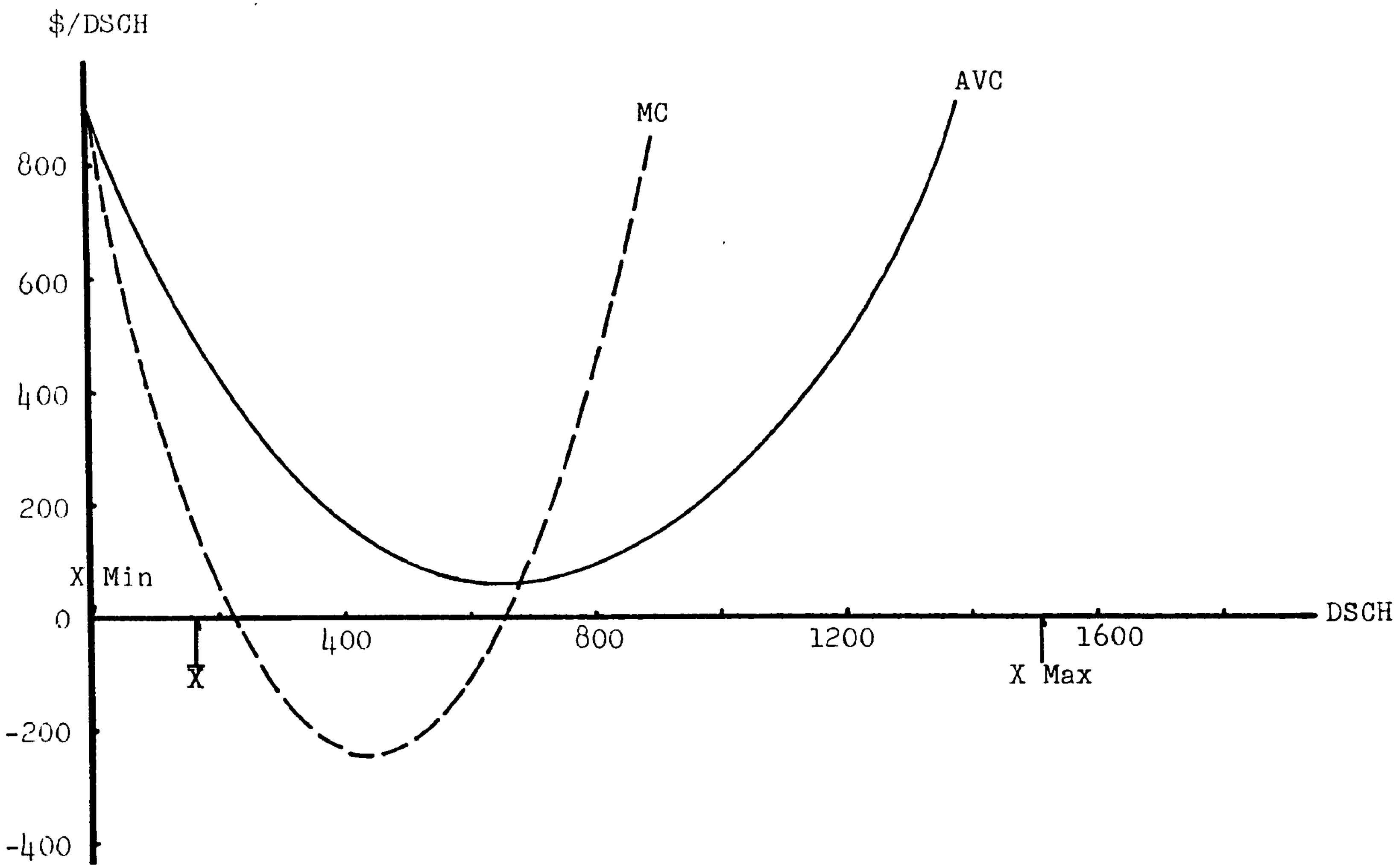

FIGURE 5

BUSINESS ADMINISTRATION DOCTORAL

show initial economies of scale which are eventually eliminated, although several of the parameter estimates are not significant at the 10% level.

In Figures 2 through 5, it can be seen that Business Administration instruction has a cost function estimate that exhibits textbook characteristic U-shaped cost curves at all output levels but that for the Masters level the entire range of values lies below the horizontal axis. The Doctoral level also lies below the x axis for a portion of the Marginal Cost function. It appears that adding a Masters program or expanding it in the Business disciplines may not involve expenses above and beyond those encountered at the undergraduate level and in fact there is some indication here that a Masters program may actually reduce total expenditures on instruction in the Business area.

Education

Table 4 presents a somewhat different picture in-so-far as the only institutional dummy variable shown to be significant for Education departments is the University of Michigan which is positive as was expected in most cases. Apparently Education departments are more homogeneous among institutions than the Business Administration departments.

TABLE 4

COST FUNCTION ESTIMATES--EDUCATION

Variable	Coefficient Estimate	Standard Error	t-value
Lower Division (LD)	58.37**	19.56	2.984**
LD^2	-.1224E-01*	.4708E-02	-2.600*
LD^3	.8327E-06**	.2495E-06	3.337**
Upper Division (UD)	14.81**	5.26	2.819**
UD^2	.3350E-03	.3194E-03	1.049
UD^3	-.9049E-08*	.5374E-08	-1.684*
Masters (M)	37.83**	11.54	3.280**
M^2	-.6131E-02**	.1699E-02	-3.609**
M^3	.1161E-06*	.5138E-07	2.260*
Doctoral (D)	54.84	58.36	.9397
D^2	.4542E-01**	.1129E-01	4.025**
D^3	-.8325E-06	.7821E-06	-1.065
LD x UD	-.2406E-02*	.1132E-02	-2.126*
LD x M	.5324E-02*	.2659E-02	2.002*
LD x D	-.1725E-01**	.5182E-02	-3.328**
UD x M	.2977E-02**	.4580E-03	6.502**
UD x D	-.6482E-02**	.2043E-02	-3.172**
M x D	.1731E-02	.1818E-02	.9523

* Significant at the ten percent level

** 1%

TABLE 4 (Continued)

Variable	Coefficient Estimate	Standard Error	t-value
Time	17960.**	2668.	6.734**
Central Michigan University	76160.	381700.	.1995
Eastern Michigan University	156300.	378100.	.4134
Ferris State College	225600.	383800.	.5878
Grand Valley State College	174300.	387300.	.4502
Lake Superior State College	81520.	418100.	.1950
Michigan Techno-logical University	136000.	414400.	.3281
Northern Michigan University	161700.	382600.	.4227
Oakland University	171300.	383900.	.4461
Saginaw Valley State College	119500.	390400.	.3062
University of Michigan	488100.*	283200.	1.723*
Wayne State University	220600.	378000.	.5837
Western Michigan University	237200	382100	.6207
Constant	-247500.	380800.	-.6500

* Significant at the ten percent level

** 1%

TABLE 4 (Continued)

Number of Observations:	217
Degrees of Freedom:	186
R^2	.99253
$\bar{R}^2$	.99132
F-Tests for Groupings of Variables	
Linear Variables	13.1546**
Square Variables	439.5261**
Cubic Variables	218.6409**
Interactions	3.3865**
Institutional Variables	11.6783**

* Significant at the ten percent level

** 1%

TABLE 5

DATA CHARACTERISTICS--EDUCATION

Variable	Mean	Standard Deviation
Lower Division (LD)	2603	3309
LD^2	.1768E+08	.3571E+08
LD^3	.1569E+12	.4149E+12
Upper Division (UD)	13530	16540
UD^2	.4552E+09	.8646E+09
UD^3	.1966E+14	.4805E+14
Masters (M)	5820	7192
M^2	.8536E+08	.1685E+09
M^3	.1642E+13	.4176E+13
Doctoral (D)	1302	3026
D^2	.1082E+08	.3145E+08
D^3	.1047E+12	.3679E+12
LD x UD	.8192E+08	.1679E+09
LD x M	.3377E+08	.6608E+08
LD x D	.8306E+07	.2543E+08
UD x M	.1842E+09	.3605E+09
UD x D	.5180E+08	.1513E+09
M x D	.2318E+08	.6796E+08

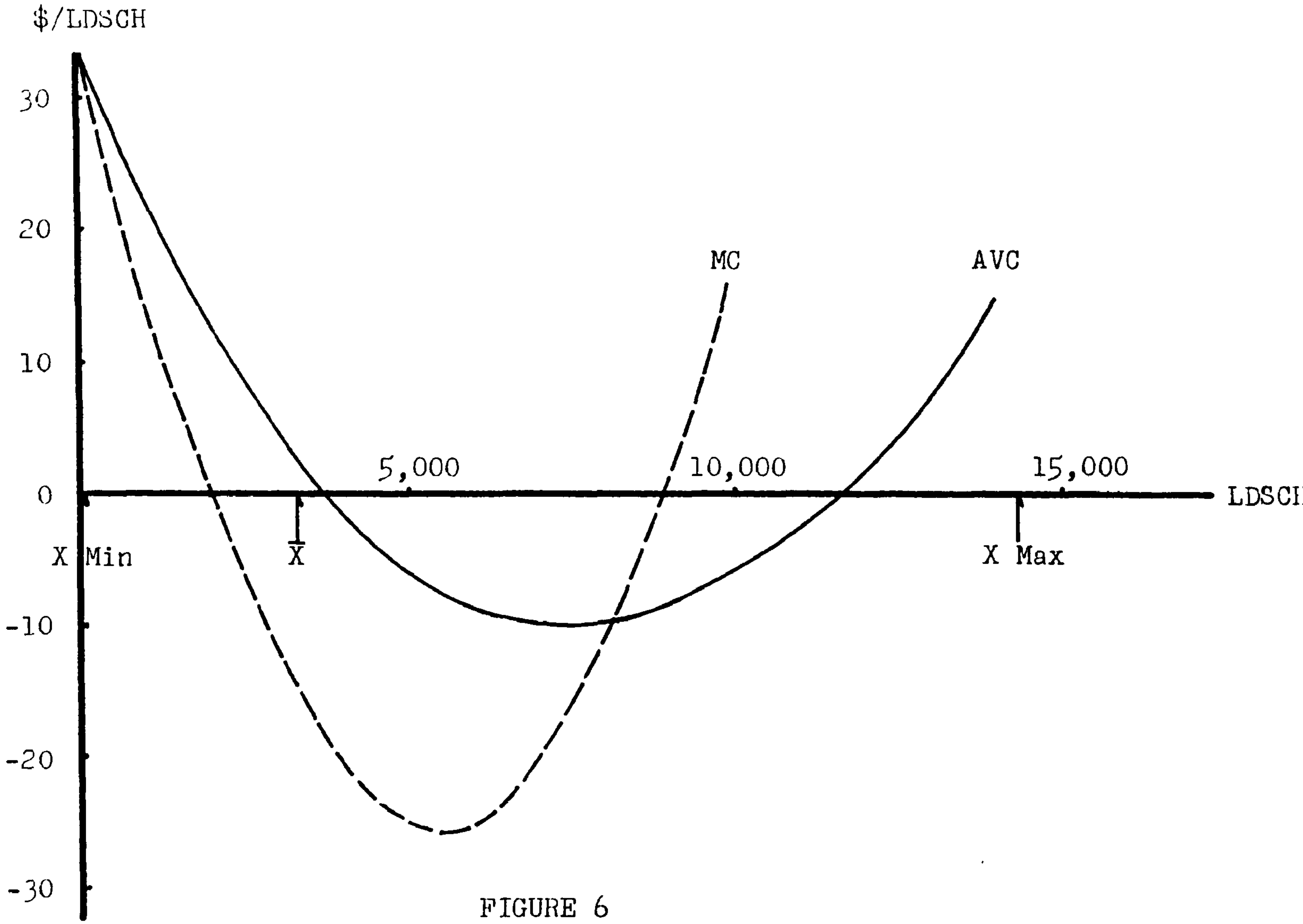

FIGURE 6

EDUCATION LOWER DIVISION

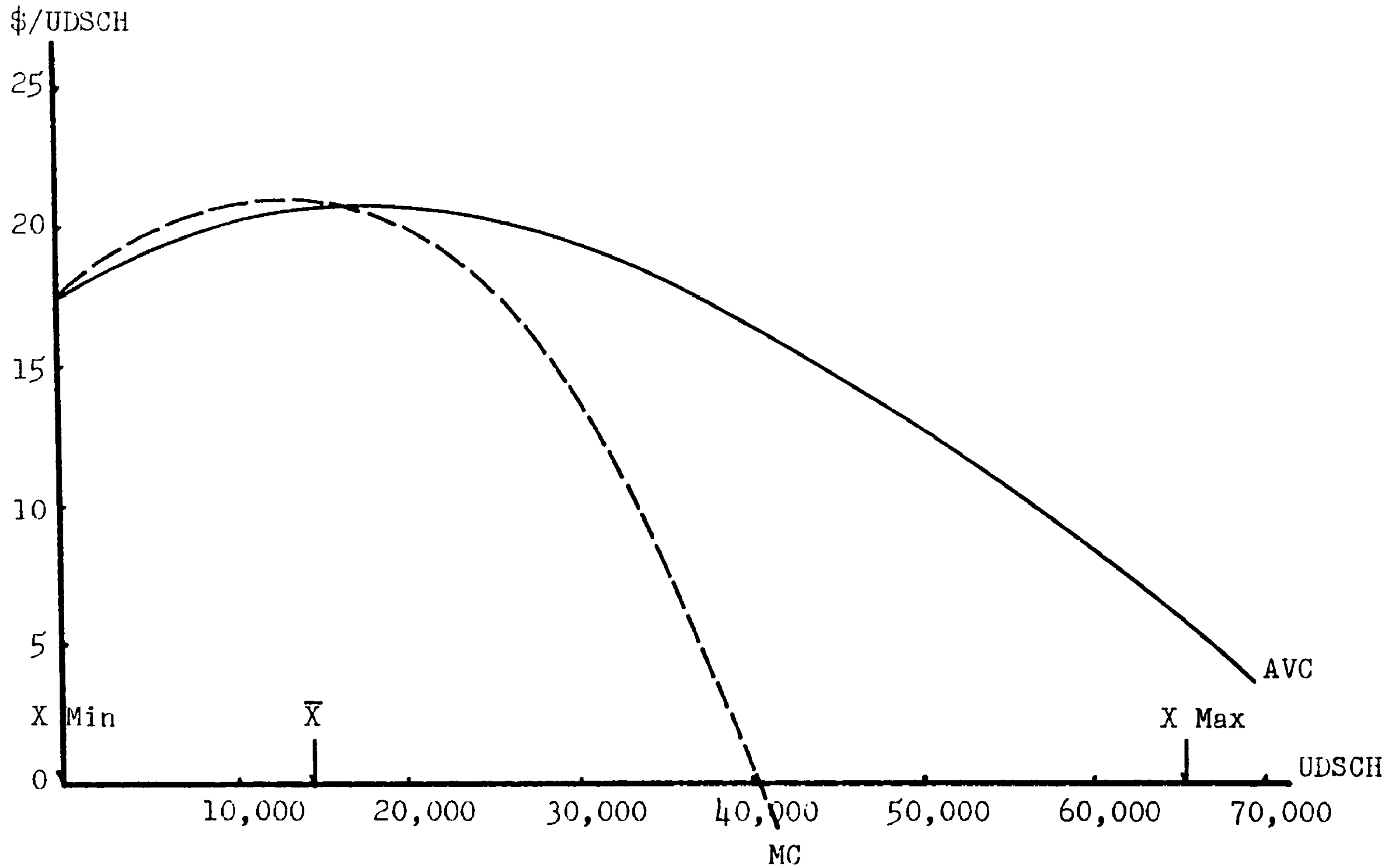

FIGURE 7

EDUCATION UPPER DIVISION

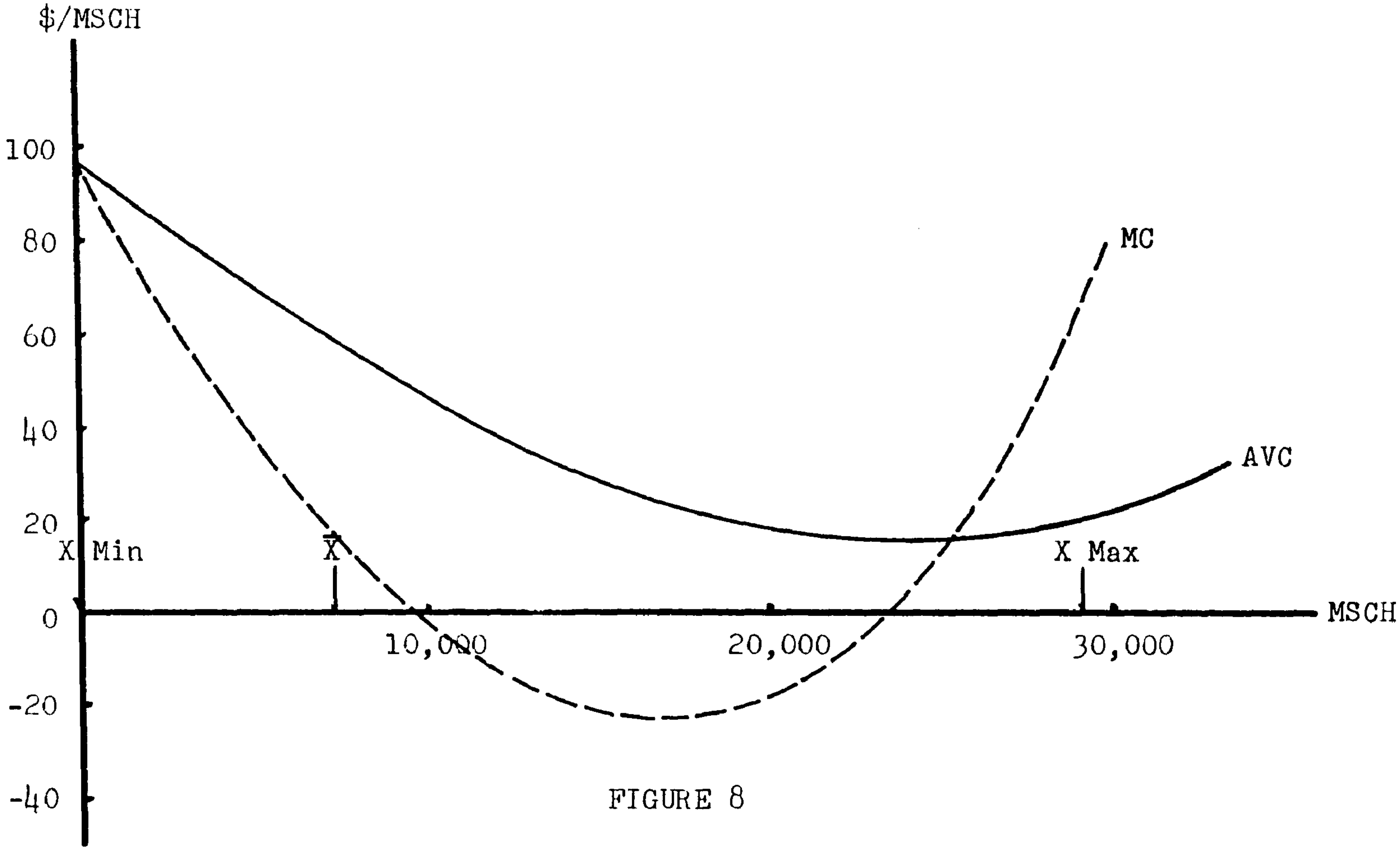

FIGURE 8

EDUCATION MASTERS

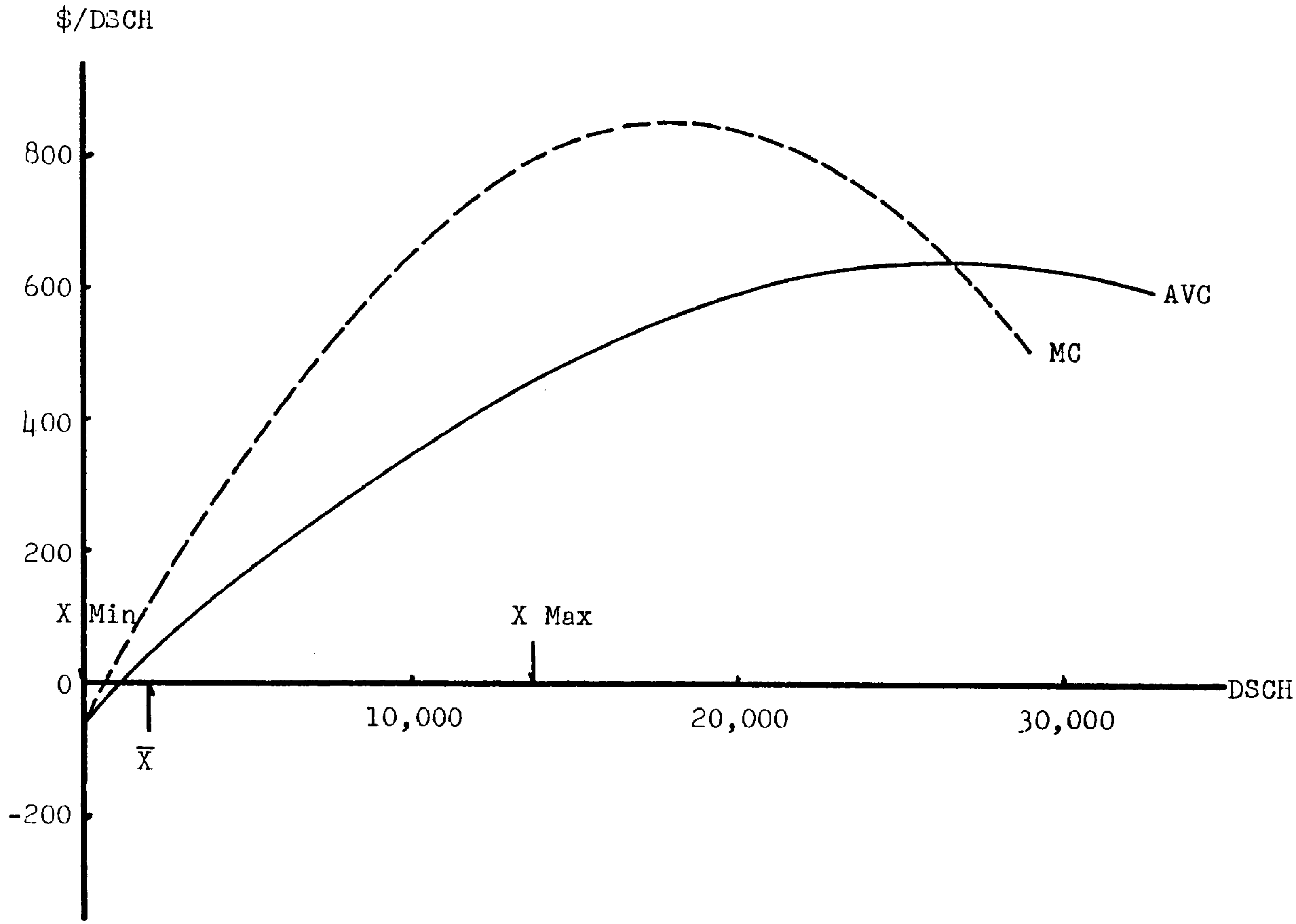

FIGURE 9

EDUCATION DOCTORAL

The following variables are significant and increase total cost in dollars per relevant unit: Linear Lower Division (\$58.37), Linear Upper Division (\$14.81), Linear Masters (\$37.83), Doctoral Squared (\$.4542E-01), Lower Division Cubed (\$.8327E-06), Masters Cubed (\$.1161E-06), Lower Division times Masters (\$.5324E-02), Upper Division times Masters (\$.2977E-02), Time (\$.1796E-05), and the University of Michigan (\$.4881E06). Significant reductions in cost are produced by the following variables in dollars per unit: Lower Division Squared (-\$.1224E-01), Masters Squared (-\$.6131E-02), Upper Division Cubed (-\$.9049E-08), Lower Division times Upper Division (-\$.2406E-02), Lower Division times Doctoral (-\$.1725E-01), and Upper Division times Doctoral (-\$.6482E-02). Each of the five groups of variables have significant F-test statistics which is of special importance for the institutional dummy variables since only one of the twelve is shown significant using individual t-tests.

Again each of the cubic terms has a sign that differs from the corresponding square term; however, in the case of Education, the signs alternate among the levels with Lower Division and Masters showing initial economies of scale and Upper Division and Doctoral showing initial diseconomies. This can be seen by examing Figures 6 through 9 where Lower Division and Masters show U-shaped cost curves and Upper Division and Doctoral show less traditional hump shapes. For Education, three of the student levels show portions of the cost curves falling below the horizontal axis for negative cost effects: Lower Division, Masters and Doctoral. The Lower Division result comes as a surprise as this was not expected *a priori*; however, it is possible that those institutions that offer a larger portion of their work at the Lower Division in larger classes and perhaps without as much variety in a more standardized core curriculum approach may reduce their costs by reducing the amount of work done at the more expensive Upper Division. While Lower Division cost curves are higher than the corresponding Upper Division curves at low levels of output, they soon fall below their Upper Division counterparts. It is not clear what the cause of this effect may be, but it may well deserve further examination at another time.

Engineering

Table 6 lists the results for the Engineering departments and shows that just as in the Education discipline all institutional dummy variables fail to attain significance with the exception of the University of Michigan although as a group they do attain significance. Here the Lower Division Linear term ($57.21), Upper Division Linear term ($39.78), Lower Division Cubed ($.1483E-05), the time trend ($32610) and the University of Michigan ($.1283E06) are cost increasing significant

TABLE 6

COST FUNCTION ESTIMATES--ENGINEERING

Variable	Coefficient Estimate	Standard Error	t-value
Lower Division (LD)	57.21*	33.93	1.686*
LD^2	-.2328E-01**	.1173E-01	-1.984**
LD^3	.1483E-05*	.8215E-06	1.806*
Upper Division (UD)	39.78*	23.15	1.718*
UD^2	-.3054E-02	.4996E-02	-.6113
UD^3	.4784E-07	.2169E-06	.2205
Masters (M)	155.21	147.88	1.050
M^2	-.1136	.129	-.8782
M^3	-.9865E-05	.2116E-04	-.4661
Doctoral (D)	-122.65	270.65	-.4532
D^2	.2422	.4377	.5532
D^3	.1877E-05	.2273E-03	.8255E-02
LD x UD	.5256E-02	.4806E-02	1.094
LD x M	.7186E-01	.5523E-01	1.301
LD x D	-.7978E-01	.5703E-01	-1.399
UD x M	.1322E-01	.1765E-01	.7491
UD x D	.2238E-01	.2497E-01	.8963
M x D	.5297E-01	.1655	.3201

* Significant at the ten percent level

** 5%

TABLE 6 (Continued)

Variable	Coefficient Estimate	Standard Error	t-value
Time	32610.**	3688.	8.842**
Central Michigan University			
Eastern Michigan University			
Ferris State College	-15040.	190600.	-.7895E-01
Grand Valley State College			
Lake Superior State College	-140000.	101100.	-1.385
Michigan Technological University	-59020.	47450.	-1.244
Northern Michigan University			
Oakland University	-41580.	72470.	-.5737
Saginaw Valley State College			
University of Michigan	128300.**	34810.	3.685**
Wayne State University	35350.	44570.	.7932
Western Michigan University	18520.	88700.	-1.483
Constant	-66630.	44930.	-1.483

* Significant at the ten percent level

** 1%

TABLE 6 (Continued)

Number of Observations:	192
Degrees of Freedom:	166
R^2	.85239
$\bar{R}^2$	.830165
F-Tests for Groupings of Variables	
Linear Variables	2.758**
Square Variables	1.192
Cubic Variables	.8743
Interactions	3.252**
Institutional Variables	2.588**

* Significant at the ten percent level

** 1%

TABLE 7

DATA CHARACTERISTICS--ENGINEERING

Variable	Mean	Standard Deviation
Lower Division(LD)	1517	1667
LD^2	.5066E+07	.1347E+08
LD^3	.2750E+11	.1317E+12
Upper Division (UD)	3948	3050
UD^2	.2484E+08	.4073E+08
UD^3	.2128E+12	.5734E+12
Masters (M)	628	586
M^2	736500	.1469E+07
M^3	.1233E+10	.4426E+10
Doctoral (D)	291	343
D^2	201400	352400
D^3	.1709E+09	.4071E09
LD x UD	.7922E+07	.1234E+08
LD x M	788700	.1125E+07
LD x D	392200	623500
UD x M	.3046E+07	.5199E+07
UD x D	.1352E+07	.2384E+07
M x D	320000	603600

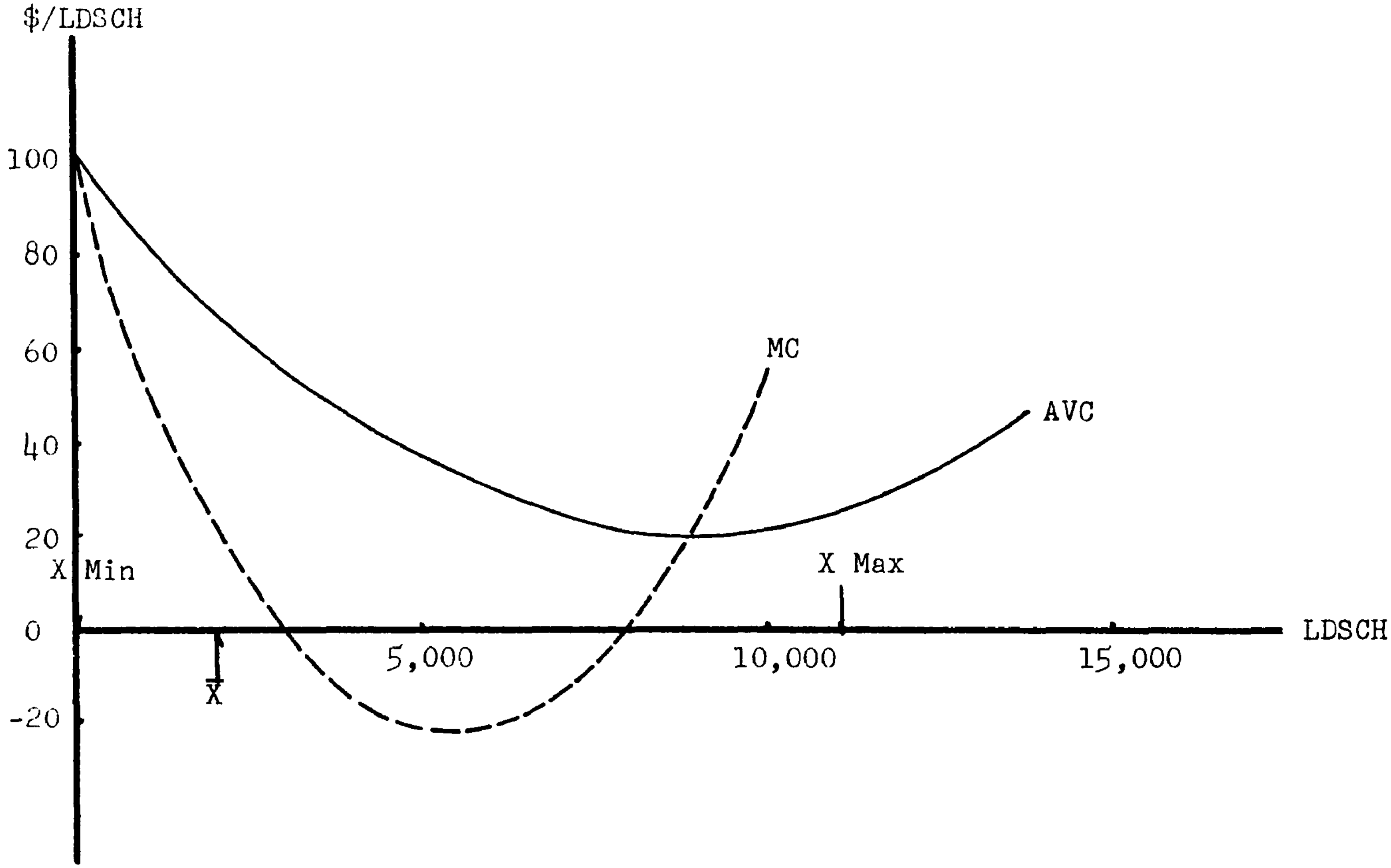

FIGURE 10

ENGINEERING LOWER DIVISION

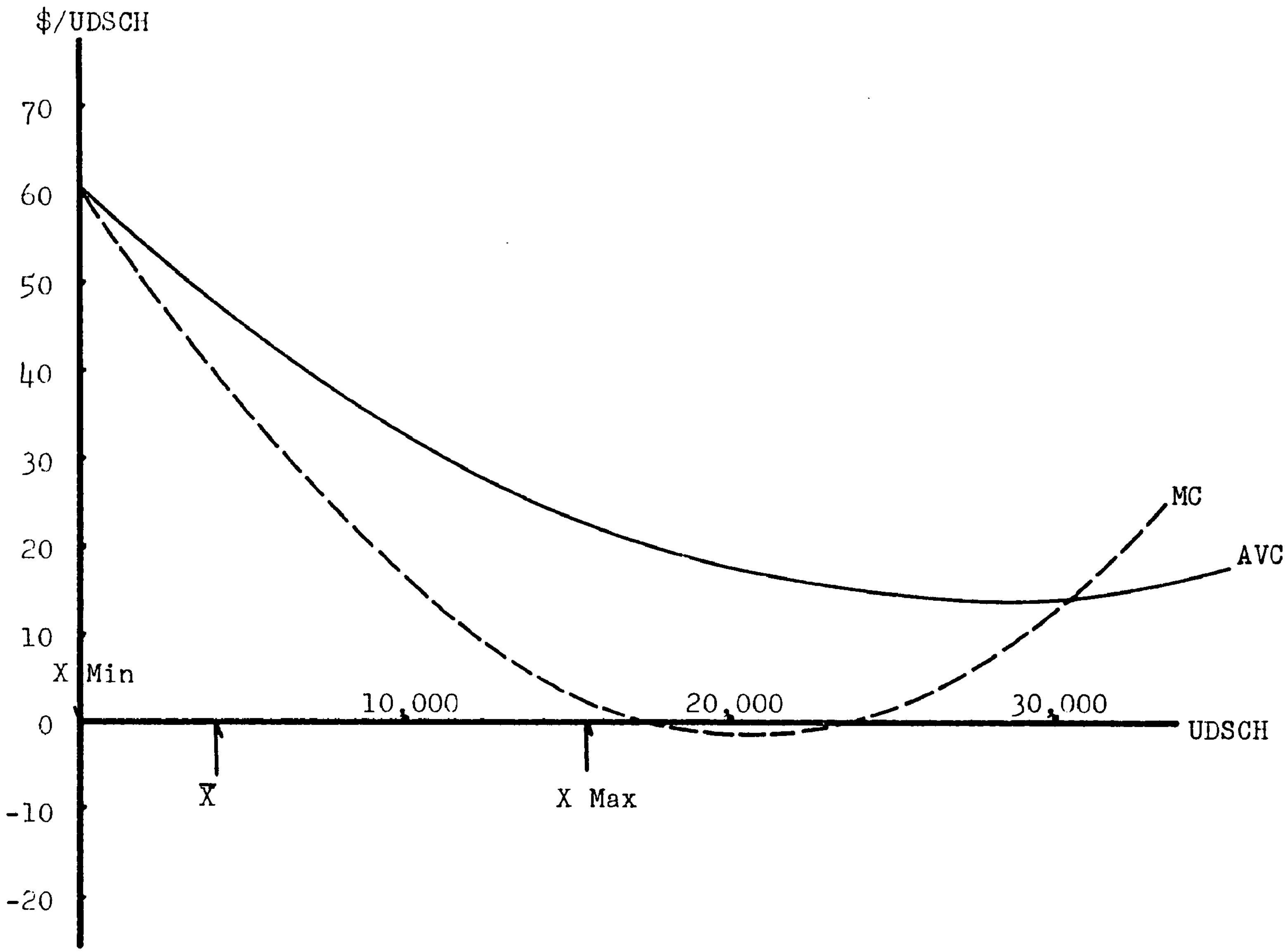

FIGURE 11

ENGINEERING UPPER DIVISION

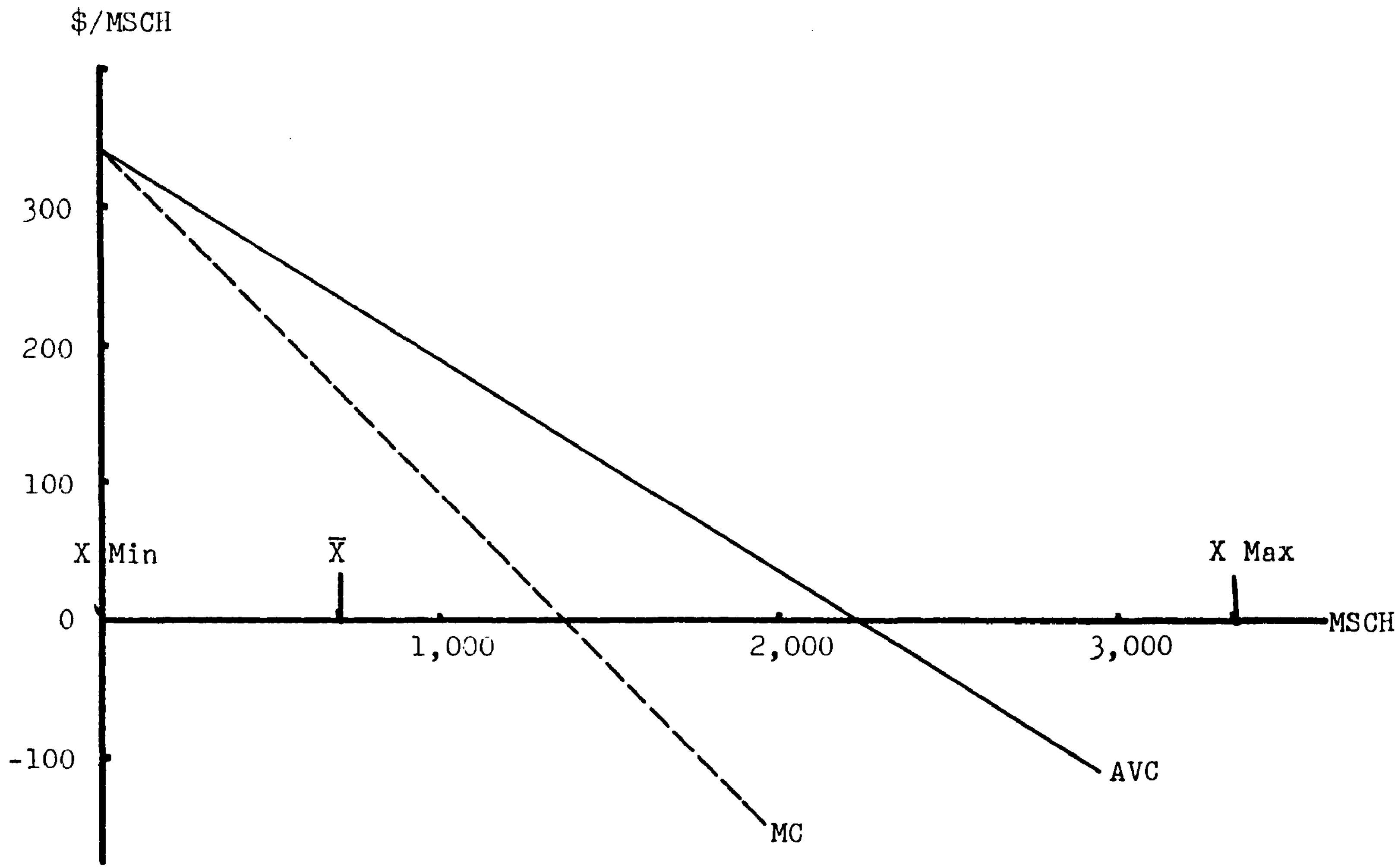

FIGURE 12

ENGINEERING MASTERS

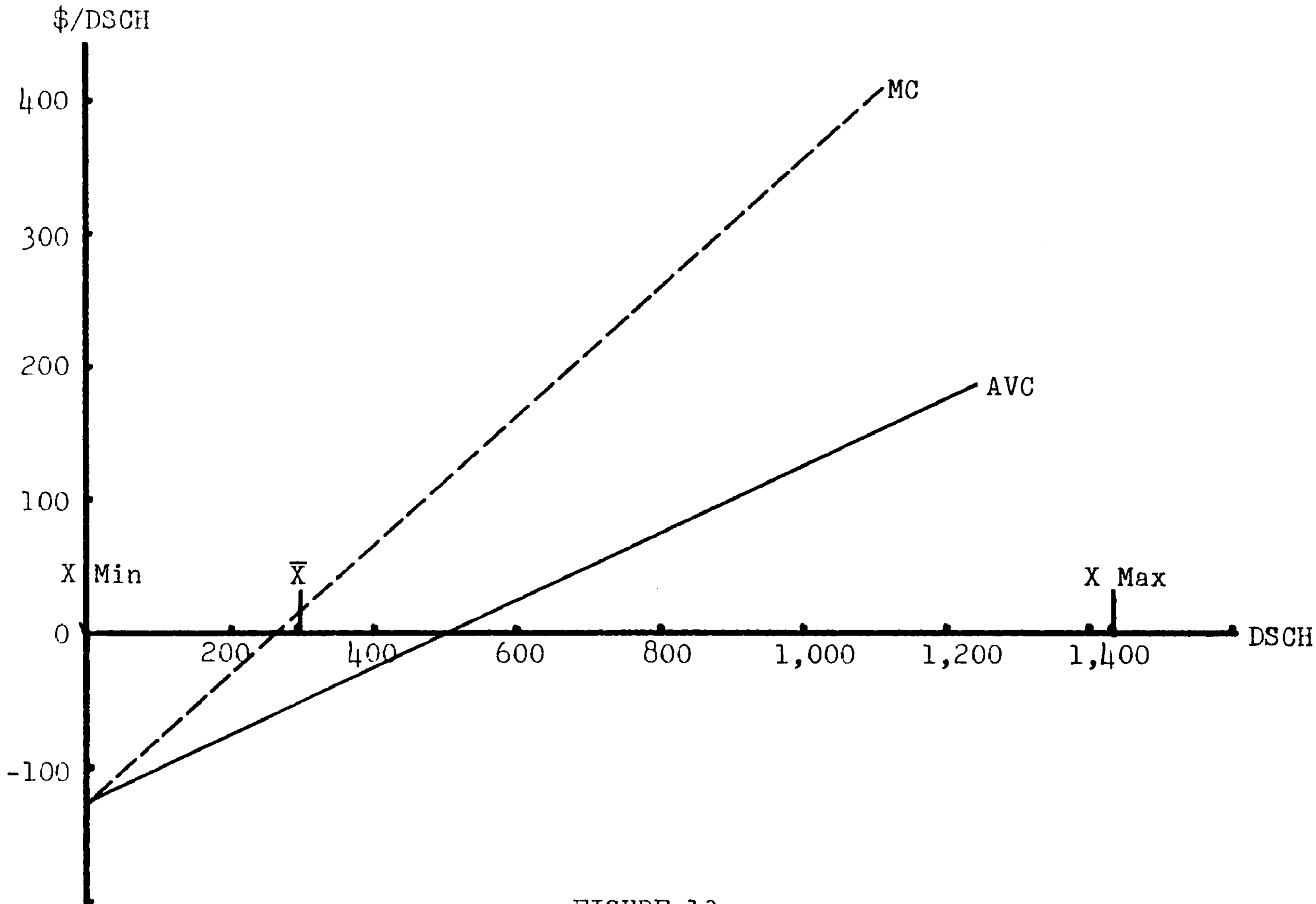

FIGURE 13

ENGINEERING DOCTORAL

variables; while only Lower Division Squared (-$.2328E-01) is significant and negative.

Again it appears that the grouping of institutions is quite homogeneous for the entire state with the exception of the University of Michigan which is more expensive for the Engineering discipline as expected.

Here, however, the first exception to the expectation of differing signs between comparable square and cubic terms is encountered at the Masters level although neither the square nor cubic term are significant at the 10% level. If both coefficients are actually negative, then there are increasing economies of scale.

Examining Figures 10 through 13 shows again another combination of interactions and relationships. The Lower Division and Upper Division again show U-shaped curves but at the Masters level and Doctoral level the functions are nearly linear and the Masters level shows economies of scale while the Doctoral level illustrates diseconomies of scale at the margin within the relevant range. In this case all four student levels show portions of at least one of the cost curves falling below the horizontal axis in a variety of ways.

For the first time it also appears that the square and cubic groupings of terms do not reach significance for the Engineering disciplines although both the individual t-tests at the Lower Division are significant. The other three groups of variables are significant for

Engineering. In fact these three groupings are significant for all six disciplines: Linear, Interactions, and Institutions. The Square and Cubic groups are significant for all disciplines with the exception of Engineering and the Social Sciences.

Humanities

The following variables are cost increasing and significant for the Humanities departments: Linear Lower Division ($24.65), Linear Masters ($138.60), Lower Division Cubed ($.6748E-08), Upper Division Cubed ($.8723E-07), Lower Division times Masters ($.2977E-02), Doctoral times Masters ($.2153), and Time ($52290). And the following variables cause costs to decrease and are significant: Lower Division Squared (-$.5100E-03), Upper Division Squared (-$.1790E-02), Upper Division times Masters (-$.6981E-02), Upper Division times Doctoral (-$.1481E-01) and all institutions with the exception of the University of Michigan and Western Michigan University. This gives reason to believe that the three institutions, the University of Michigan, Western Michigan University and Michigan State University are somewhat similar in their Humanities cost structure and that Michigan State is clearly among the more expensive in the state.

TABLE 8

COST FUNCTION ESTIMATES--HUMANITIES

Variable	Coefficient Estimate	Standard Error	t-value
Lower Division (LD)	24.65**	5.850	4.215**
LD^2	-.5100E-03*	.2633E-03	-1.936*
LD^3	.6748E-08*	.3018E-08	2.236*
Upper Division (UD)	13.89	11.55	1.203
UD^2	-.1790E-02*	.1035E-02	-1.730*
UD^3	.8723E-07**	.2435E-07	3.582**
Masters (M)	138.59*	59.01	2.349*
M^2	.7394E-02	.3233E-01	.2287
M^3	-.7621E-05	.4769E-05	-1.598
Doctoral (D)	-34.00	106.33	-.3198
D^2	-.3366E-01	.1092	-.3083
D^3	-.7974E-05	.2981E-04	-.2675
LD x UD	-.3080E-03	.1962E-03	-1.570
LD x M	.2977E-02**	.1126E-02	2.644**
LD x D	-.1476E-02	.2152E-02	-.6859
UD x M	-.6981E-02*	.3354E-02	-2.081*
UD x D	-.1481E-01**	.3687E-02	-4.016**
M x D	.2153**	.2573E-01	8.364**

*   Significant at the ten percent level

**   1%

TABLE 8 (Continued)

Variable	Coefficient Estimate	Standard Error	t-value
Time	52290.**	2863.	18.26**
Central Michigan University	-154600.**	41600.	-3.716**
Eastern Michigan University	-107000.*	43470.	-2.462*
Ferris State College	-203200.**	48850.	-4.160**
Grand Valley State College	-213800.**	49870.	-4.288**
Lake Superior State College	-305500.**	107800.	-2.833**
Michigan Techno-logical University	-103800.*	60470.	-1.717*
Northern Michigan University	-150900.**	44170.	-3.417**
Oakland University	-133100.**	41700	-3.192**
Saginaw Valley State College	-290500.**	79300.	-3.663**
University of Michigan	-15210.	30590.	-.4975
Wayne State University	-57380*	31540.	-1.819*
Western Michigan University	-24160.	36760.	-.6572
Constant	-95790.**	35460.	-2.701**

*   Significant at the ten percent level

**   1%

TABLE 8 (Continued)

Number of Observations:	485
Degrees of Freedom:	454
R^2	.87962
$\bar{R}^2$	.87166
F-Tests for Groupings of Variables	
Linear Variables	14.73**
Square Variables	2.66**
Cubic Variables	5.70**
Interactions	3.67**
Institutional Variables	12.31**

* Significant at the ten percent level

** 1%

TABLE 9

DATA CHARACTERISTICS--HUMANITIES

Variable	Mean	Standard Deviation
Lower Division (LD)	12420	12860
LD^2	.3193E+09	.6092E+09
LD^3	.1141E+14	.2964E+14
Upper Division (UD)	7236	6484
UD^2	.9431E+08	.1483E+09
UD^3	.1591E+13	.3475E+13
Masters (M)	1052	1239
M^2	.2638E+07	.5155E+07
M^3	.8744E+10	.2294E+11
Doctoral (D)	388	693
D^2	630200	.1534E+07
D^3	.1259E+10	.3612E+10
LD x UD	.13608E+09	.2188E+09
LD x M	.1822E+08	.3325E+08
LD x D	.5858E+07	.1327E+08
UD x M	.1360E+08	.2293E+08
UD x D	.4963E+07	.1160E+08
M x D	997400	.2394E+07

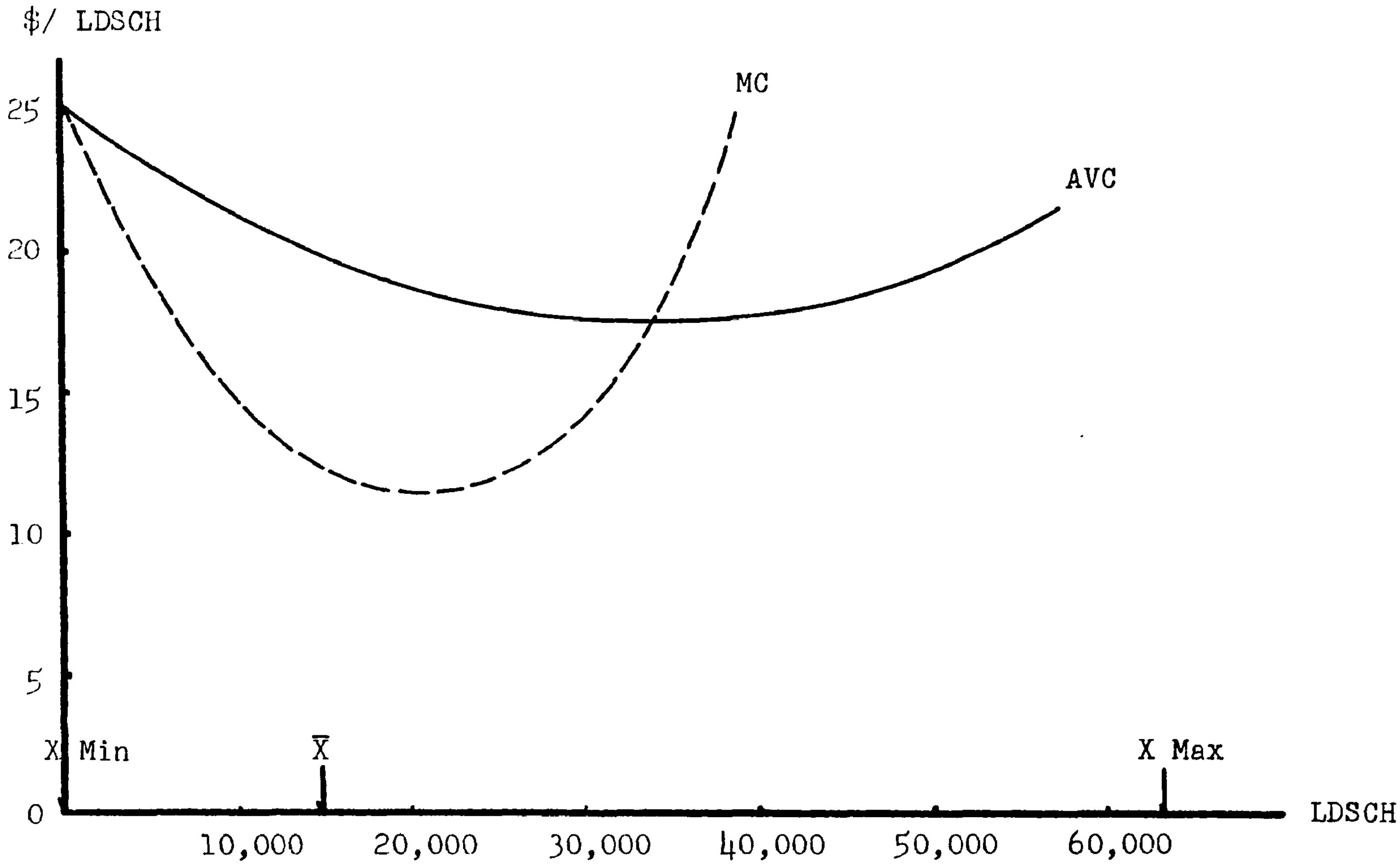

FIGURE 14

HUMANITIES LOWER DIVISION

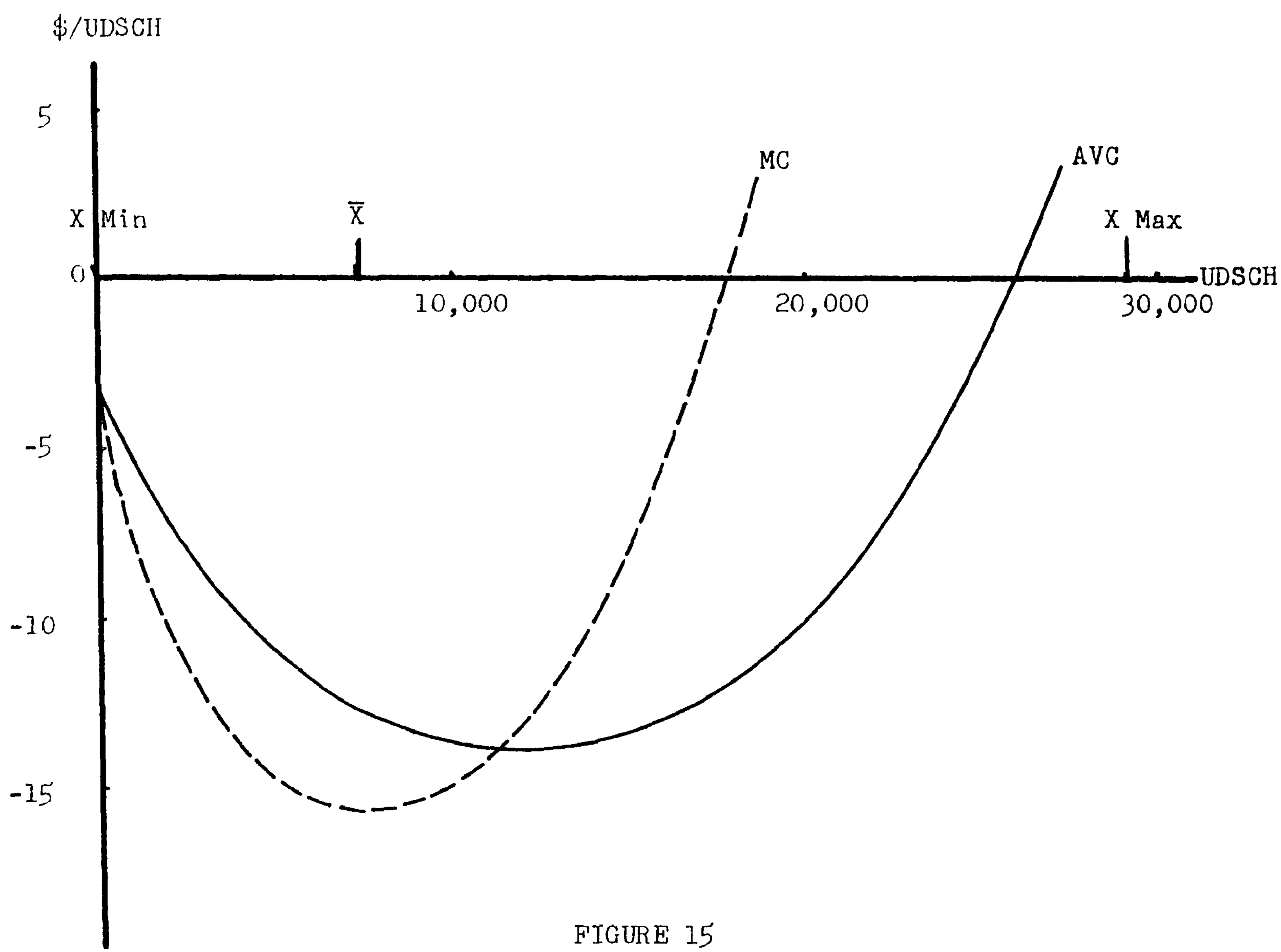

FIGURE 15

HUMANITIES UPPER DIVISION

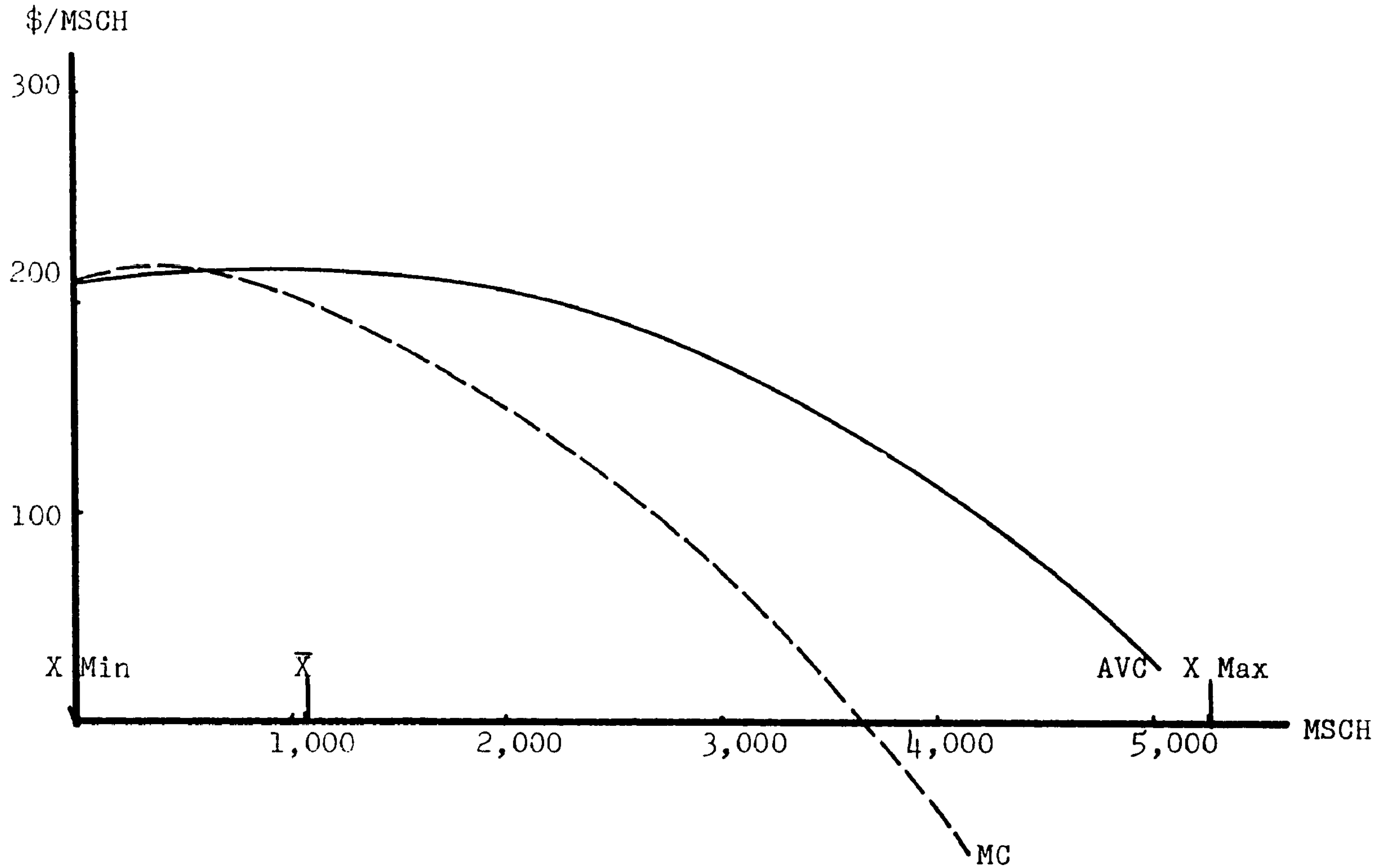

FIGURE 16

HUMANITIES MASTERS

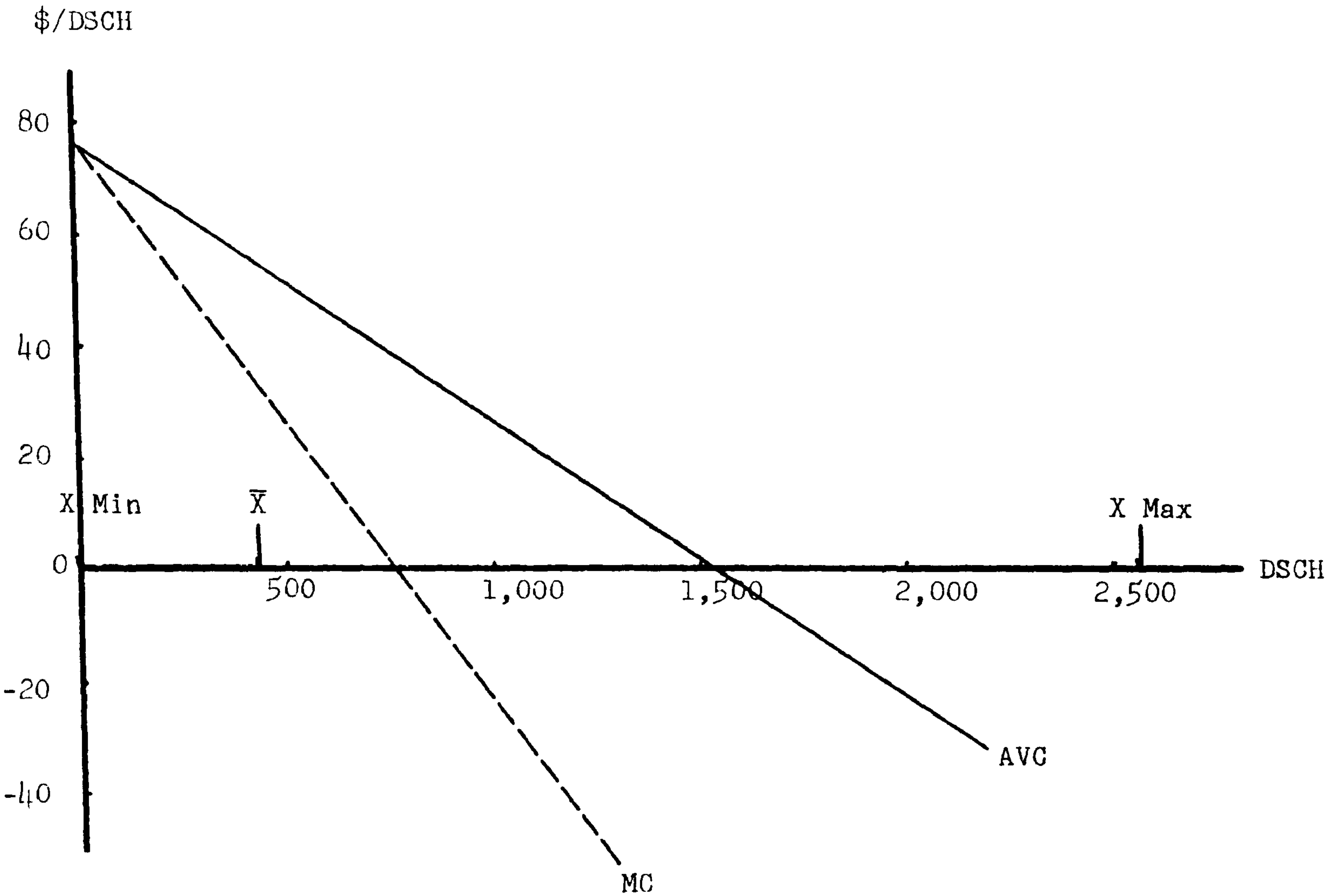

FIGURE 17

HUMANITIES DOCTORAL

The five groups of variables all attain significance and the signs of the square and cubic terms differ for each student level with the exception of the Doctoral level; but just as in the case of the Masters level for Engineering, neither of the coefficients is significant where signs do not differ. The cost curves are U-shaped in the Humanities discipline for the Lower Division and the Upper Division although the Upper Division lies in the negative quadrant for most of the relevant range. The Masters level has a slightly inverted shape and the Doctoral level again shows an approximation of a linear relation with definite signs of economies of scale.

Natural Sciences

Table 10 presents the results for the Natural Science discipline where it is seen that the following variables are significant and increase total cost: Lower Division Linear (\$24.18), Linear Doctoral (\$383.40), Masters Squared (\$.4344E-01), Doctoral Squared (\$.1161), Upper Division times Masters (\$.2909E-01), Time (\$37300), University of Michigan (\$.1242E06), Wayne State University (\$.8197E05), and Western Michigan University (\$.1221E06). The variables which are significant and reduce costs are: Linear Masters (-\$121.10), Upper Division Squared (-\$.7121E-02), Masters Cubed (-\$.3993E-05), Doctoral Cubed (-\$.1168E-04), Lower Division times Masters

TABLE 10

COST FUNCTION ESTIMATES--NATURAL SCIENCES

Variable	Coefficient Estimate	Standard Error	t-value
Lower Division (LD)	24.18**	8.060	3.001**
LD^2	-.2847E-03	.4444E-03	-.6407
LD^3	-.7138E-09	.6413E-08	-.1113
Upper Division (UD)	21.35	21.97	.9718
UD^2	-.7121E-02*	.3397E-02	-2.097*
UD^3	.1713E-06	.1625E-06	1.054
Masters (M)	-121.06*	51.07	-2.370*
M^2	.4344E-01*	.2365E-01	1.837*
M^3	-.3993E-05*	.1828E-05	2.184*
Doctoral (D)	383.43**	67.27	5.700**
D^2	.1161*	.4661E-01	2.490*
D^3	-.1168E-04**	.4383E-05	-2.664**
LD x UD	.1209E-02	.7478E-03	1.616
LD x M	-.7926E-02**	.2387E-02	-3.320**
LD x D	-.3103E-02	.3271E-02	-.9486
UD x M	.2909E-01**	.8223E-02	3.538**
UD x D	.3429E-02	.1037E-01	.3304
M x D	-.1074**	.1846E-01	-5.818**

* Significant at the ten percent level

** 1%

TABLE 10 (Continued)

Variable	Coefficient Estimate	Standard Error	t-value
Time	37300.**	3033.	12.30**
Central Michigan University	53300.	48090.	1.108
Eastern Michigan University	58400.	44930.	1.300
Ferris State College	-110100.*	46770.	-2.354*
Grand Valley State College	-91570.	55840.	-1.640
Lake Superior State College	-147600.*	77440.	-1.906*
Michigan Techno-logical University	21720.	41070.	.5288
Northern Michigan University	-25850.	45290.	-.5708
Oakland University	125.7	47310.	.2658E-02
Saginaw Valley State College	-143600.*	84670.	-1.696*
University of Michigan	124200.**	28710.	4.328**
Wayne State University	81970.*	34000.	2.411*
Western Michigan University	122100.**	43530.	2.805**
Constant	-120800.**	36540.	-3.306**

* Significant at the ten percent level

** 1%

TABLE 10 (Continued)

Number of Observations:	399
Degrees of Freedom:	368
R^2	.91287
$\bar{R}^2$	.90576
F-Tests for Groupings of Variables	
Linear Variables	13.26**
Square Variables	2.106**
Cubic Variables	4.109**
Interactions	5.4.4**
Institutional Variables	15.427**

* Significant at the ten percent level

** 1%

TABLE 11

DATA CHARACTERISTICS--NATURAL SCIENCES

Variable	Mean	Standard Deviation
Lower Division (LD)	10220	10770
LD^2	.2202E+09	.4413E+09
LD^3	.6733E+13	.1865E+14
Upper Division (UD)	4476	3719
UD^2	.3383E+08	.5433E+08
UD^3	.3409E+12	.8102E+12
Masters (M)	1052	1442
M^2	.3182E+07	.8888E+07
M^3	.1508E+11	.6195E+11
Doctoral (D)	601	1030
D^2	.1418E+07	.4122E+07
D^3	.4687E+08	.2042E11
LD x UD	.7087E+08	.1212E+09
LD x M	.1808E+08	.4042E+08
LD x D	.1163E+08	.2925E+08
UD x M	.9219E+07	.2020E+08
UD x D	.5643E+07	.1362E+08
M x D	.1331E+07	.5545E+07

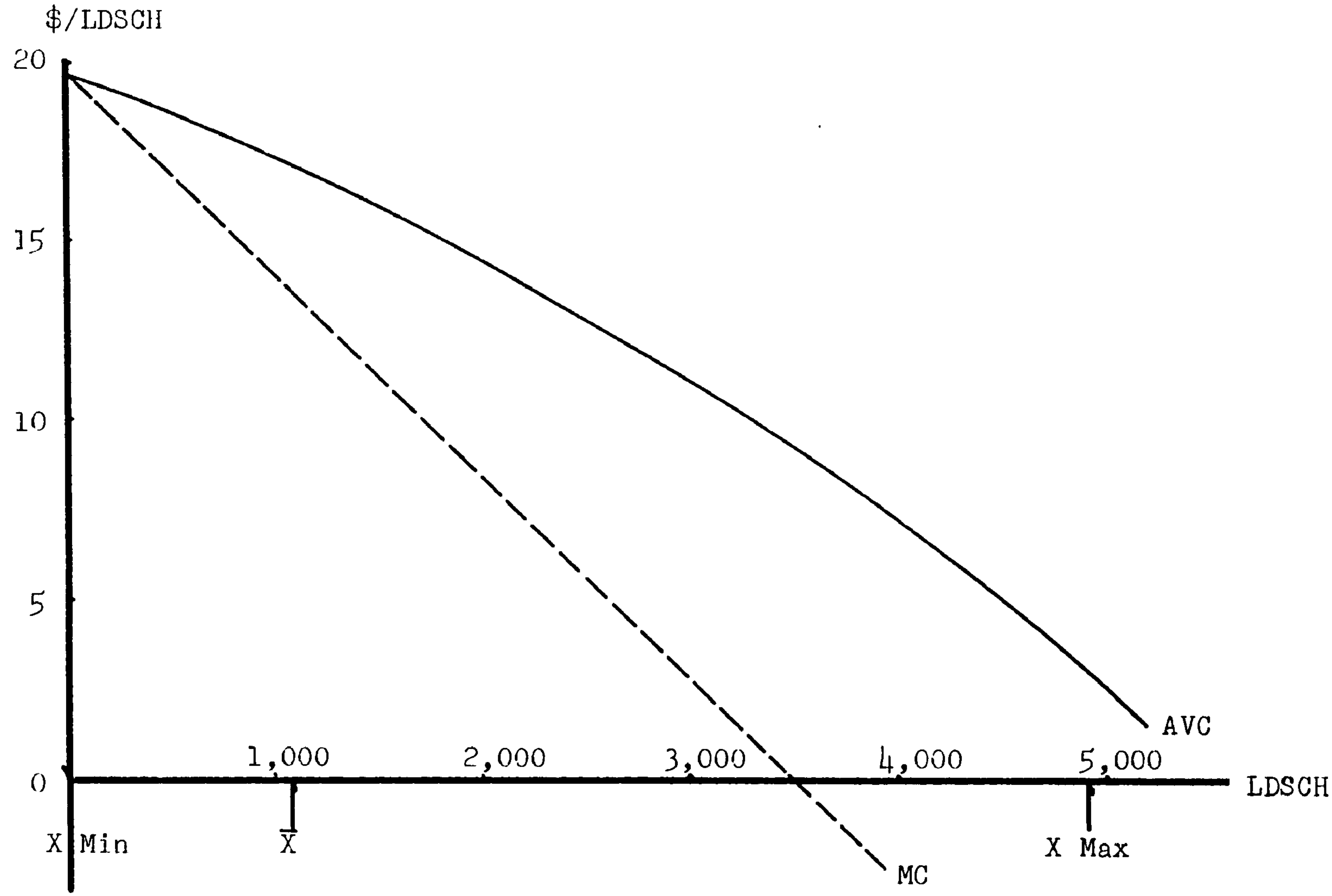

FIGURE 18

NATURAL SCIENCES LOWER DIVISION

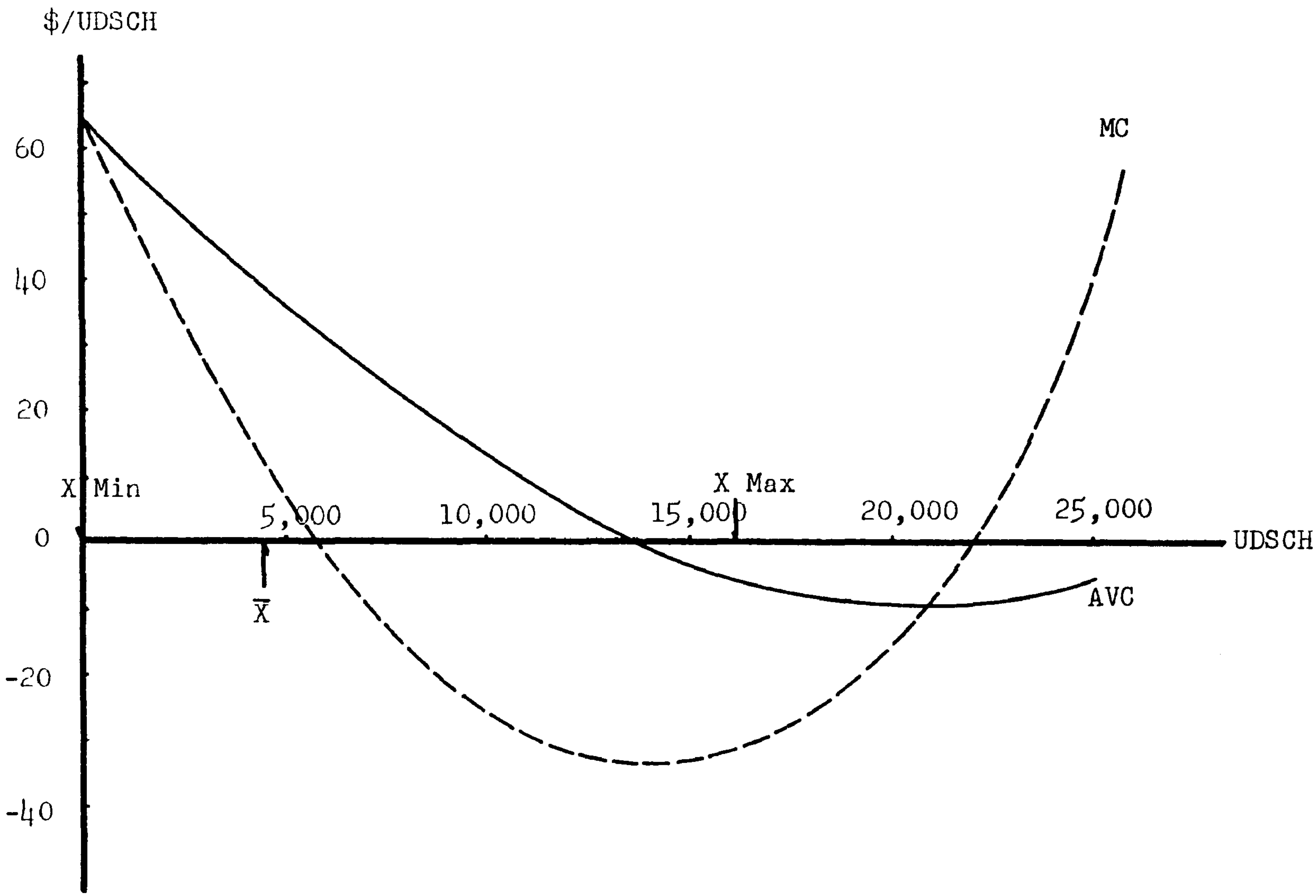

FIGURE 19

NATURAL SCIENCES UPPER DIVISION

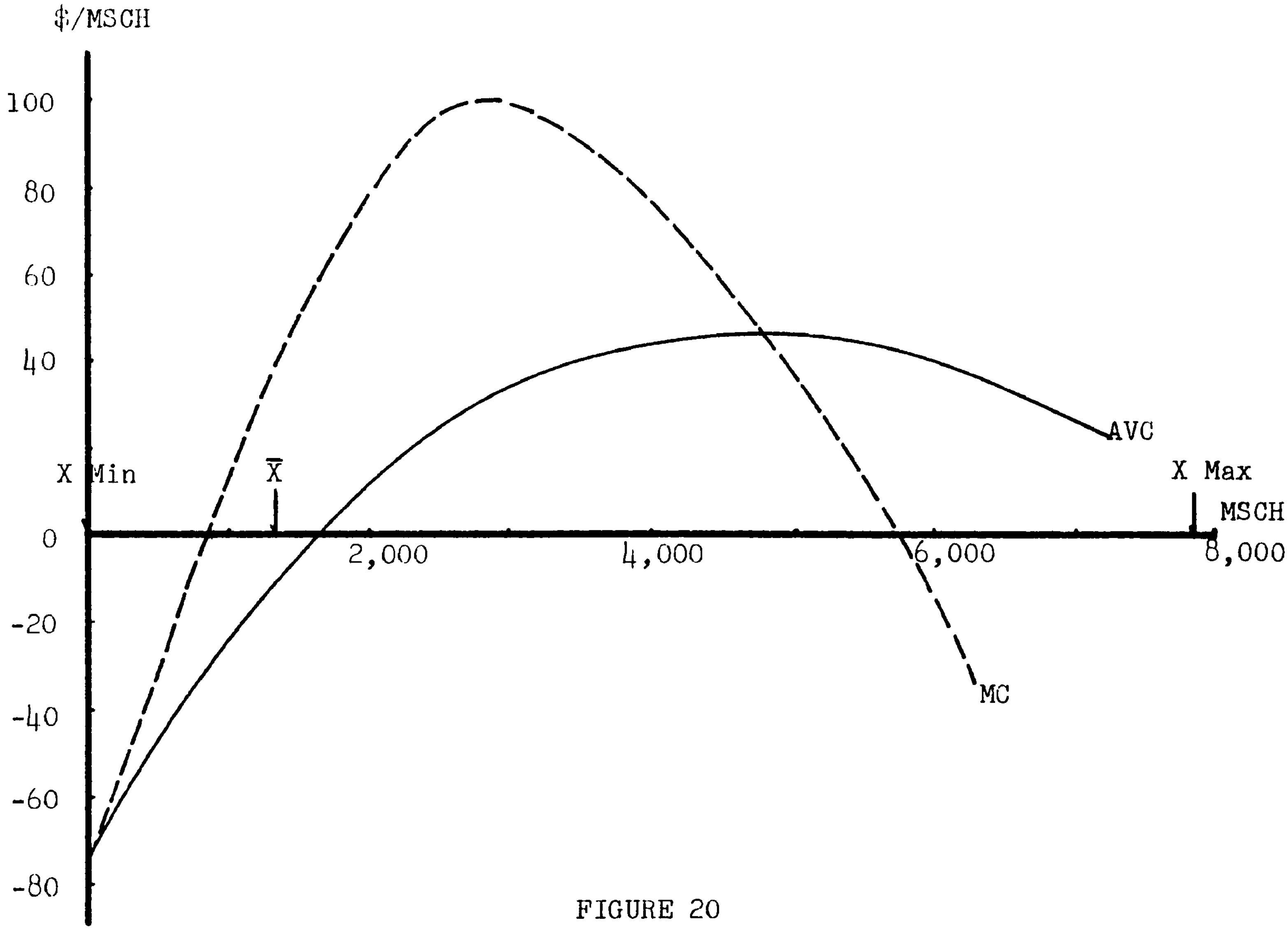

FIGURE 20

NATURAL SCIENCES MASTERS

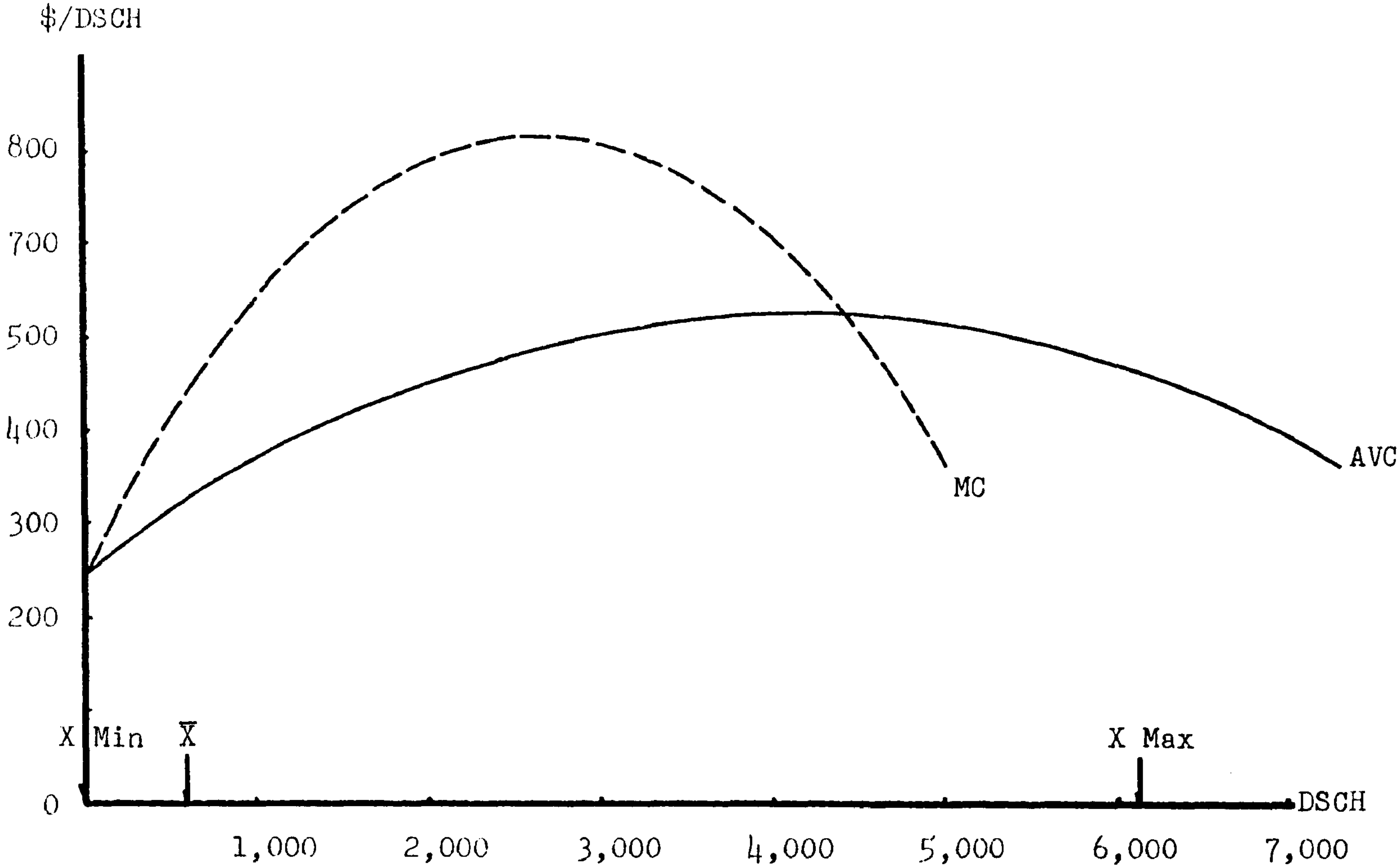

FIGURE 21

NATURAL SCIENCES DOCTORAL

(-$.7926E-02), Masters times Doctoral (-$.1074), Ferris State College (-$.1101E06), and Saginaw Valley State College (-.1436E06). Again each of the five groups of variables is significant.

At each level except the Lower Division the sign of the Cubic and Square terms differs and at the Lower Division, neither the Square nor the Cubic term is significant at the 10 percent level.

For the Natural Sciences, the Lower Division cost curves approximate linear functions, the Upper Division takes the U-shape and the graduate levels are both inverted U-shaped. The Upper Division curves have negative values for a surprising portion of their range, the Masters level curves begin in negative territory but rapidly become positive and the Doctoral curves and Lower Division curves are universally in the positive quadrant. These can be seen in Figures 18 through 21.

Social Sciences

The results for the Social Science discipline are found in Table 12. Variables which are significant and increase costs are: Upper Division ($20.73), Doctoral Linear ($121), Upper Division Cubed ($.2558E-07), Upper Division times Doctoral ($.6684E-02), Time ($27020), and University of Michigan ($65450). Those variables which are significant and reduce costs are: Upper Division

TABLE 12

COST FUNCTION ESTIMATES--SOCIAL SCIENCES

Variable	Coefficient Estimates	Standard Error	t-value
Lower Division (LD)	1.072	6.176	.1736
LD^2	.2091E-03	.4289E-03	.4875
LD^3	-.1501E-08	.7536E-08	-.1992
Upper Division (UD)	20.73*	8.095	2.560*
UD^2	-.1154E-02*	.6320E-03	-1.826*
UD^3	.2558E-07*	.1539E-07	1.663*
Masters (M)	27.43	25.07	1.094
M^2	.3098E-02	.5147E-02	.6020
M^3	-.1516E-06	.2508E-06	-.6046
Doctoral (D)	121.04*	55.02	2.200*
D^2	-.1500E-01	.1840E-01	-.8153
D^3	.1593E-05	.2064E-05	.7716
LD x UD	.2298E-03	.3932E-03	.5844
LD x M	.1513E-03	.2077E-02	.7283E-01
LD x D	.1188E-02	.2187E-02	.5434
UD x M	.6014E-03	.2077E-02	.2895
UD x D	.6684E-02**	.2026E-02	3.300**
M x D	-.3874E-01**	.1147E-01	-3.377**

* Significant at the ten percent level

** 1%

TABLE 12 (Continued)

Variable	Coefficient Estimate	Standard Error	t-value
Time	27020.**	2160.	12.51**
Central Michigan University	-51790.*	29420.	-1.760*
Eastern Michigan University	-35430.	32060.	-1.105
Ferris State College	-95327.**	31390.	-3.036**
Grand Valley State College	-36660.	39860.	-.9197
Lake Superior State College	-167800.**	62530.	-2.684**
Michigan Techno-logical University	-157700.*	69340.	-2.274*
Northern Michigan University	-71070.*	28620.	-2.483*
Oakland University	-65830.*	32520.	-2.024*
Saginaw Valley State College	-162000.**	57910.	-2.797**
University of Michigan	65450.**	22070.	2.966**
Wayne State University	26160.	20970.	1.248
Western Michigan University	-33134.8	25720.	-1.288
Constant	-25440.	27110.	-.9385

* Significant at the ten percent level

** 1%

TABLE 12 (Continued)

Number of Observations:	344
Degrees of Freedom:	313
R^2	.92769
$\bar{R}^2$	.92076
F-Tests for Groupings of Variables	
Linear Variables	6.190**
Square Variables	.9957
Cubic Variables	.7792
Interactions	3.434**
Institutional Variables	7.944**

* Significant at the ten percent level

** 1%

TABLE 13

DATA CHARACTERISTICS--SOCIAL SCIENCES

Variable	Mean	Standard Deviation
Lower Division (LD)	8512	7550
LD^2	.1293E+09	.2526E+09
LD^3	.2874E+13	.8928E+13
Upper Division (UD)	7255	6082
UD^2	.8951E+08	.1476E+09
UD^3	.1487E+13	.3711E+13
Masters (M)	1413	1717
M^2	.4937E+07	.1863E+08
M^3	.3404E+11	.2586E+12
Doctoral (D)	606	1136
D^2	.1654E+07	.5659E+07
D^3	.6754E+10	.3472E+11
LD x UD	.8698E+08	.1321E+09
LD x M	.1349E+08	.2093E+08
LD x D	.8820E+07	.2265E+08
UD x M	.1445E+08	.2285E+08
UD x D	.9014E+07	.2282E+08
M x D	.1575E+07	.3765E+07

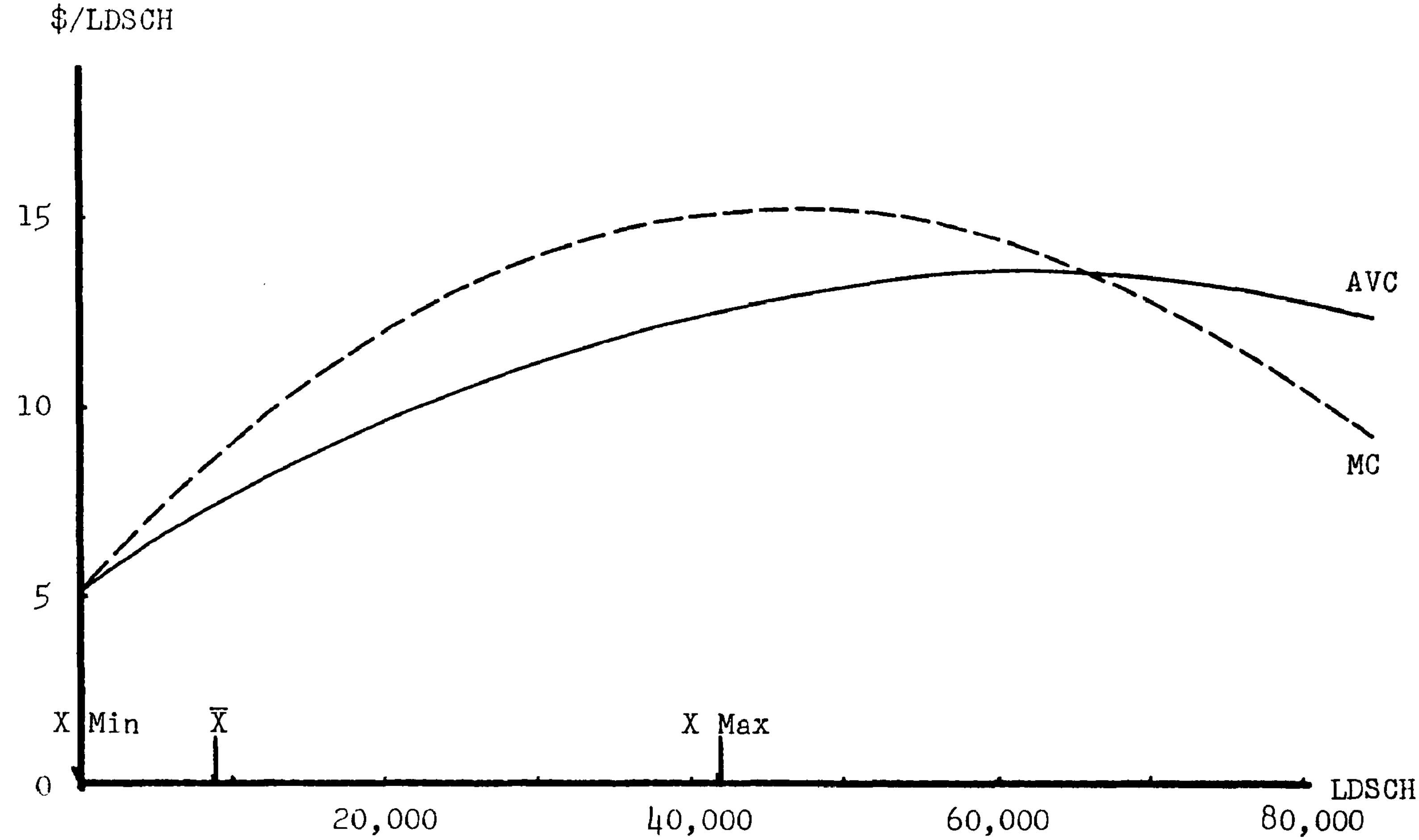

FIGURE 22

SOCIAL SCIENCES LOWER DIVISION

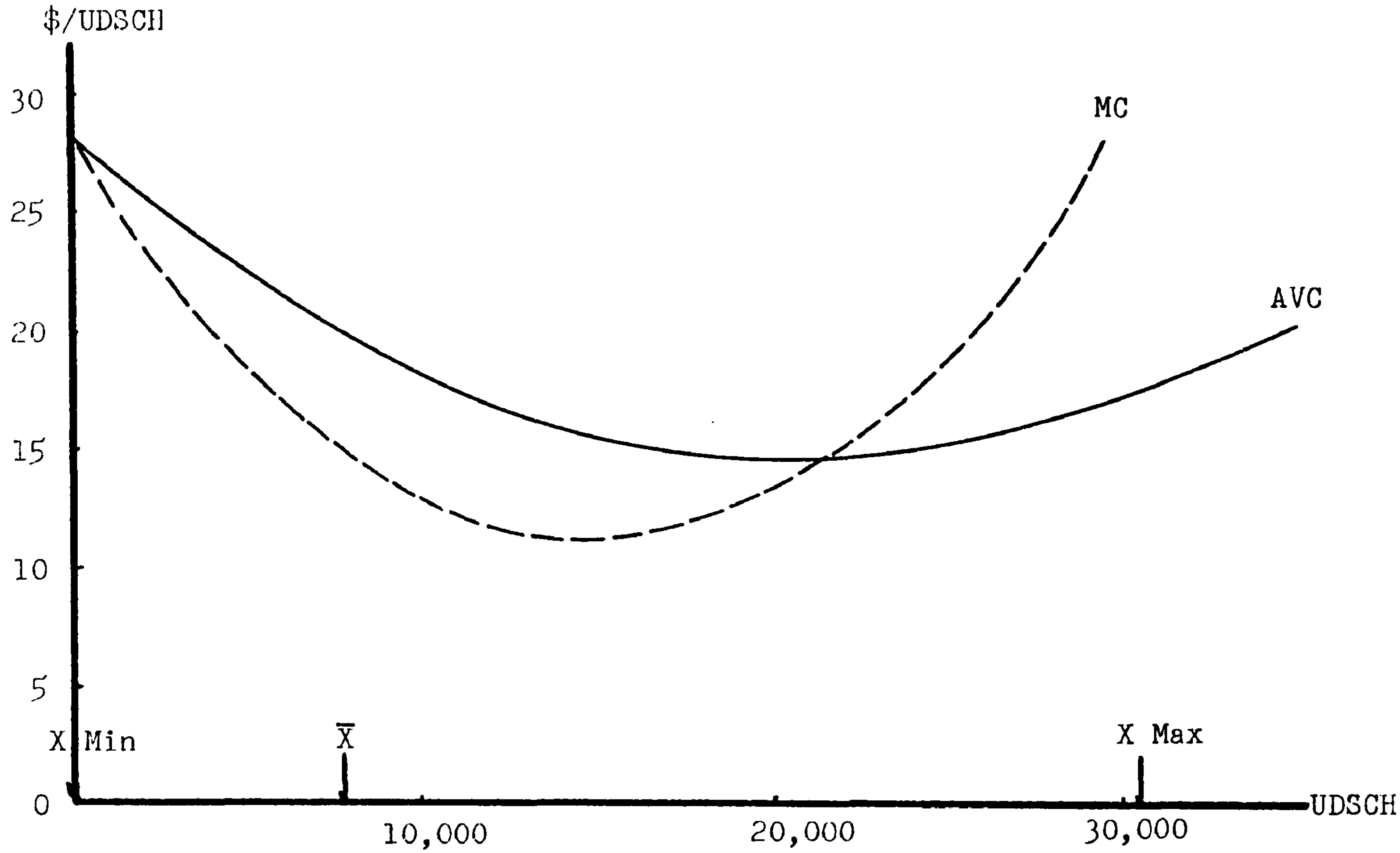

FIGURE 23

SOCIAL SCIENCES UPPER DIVISION

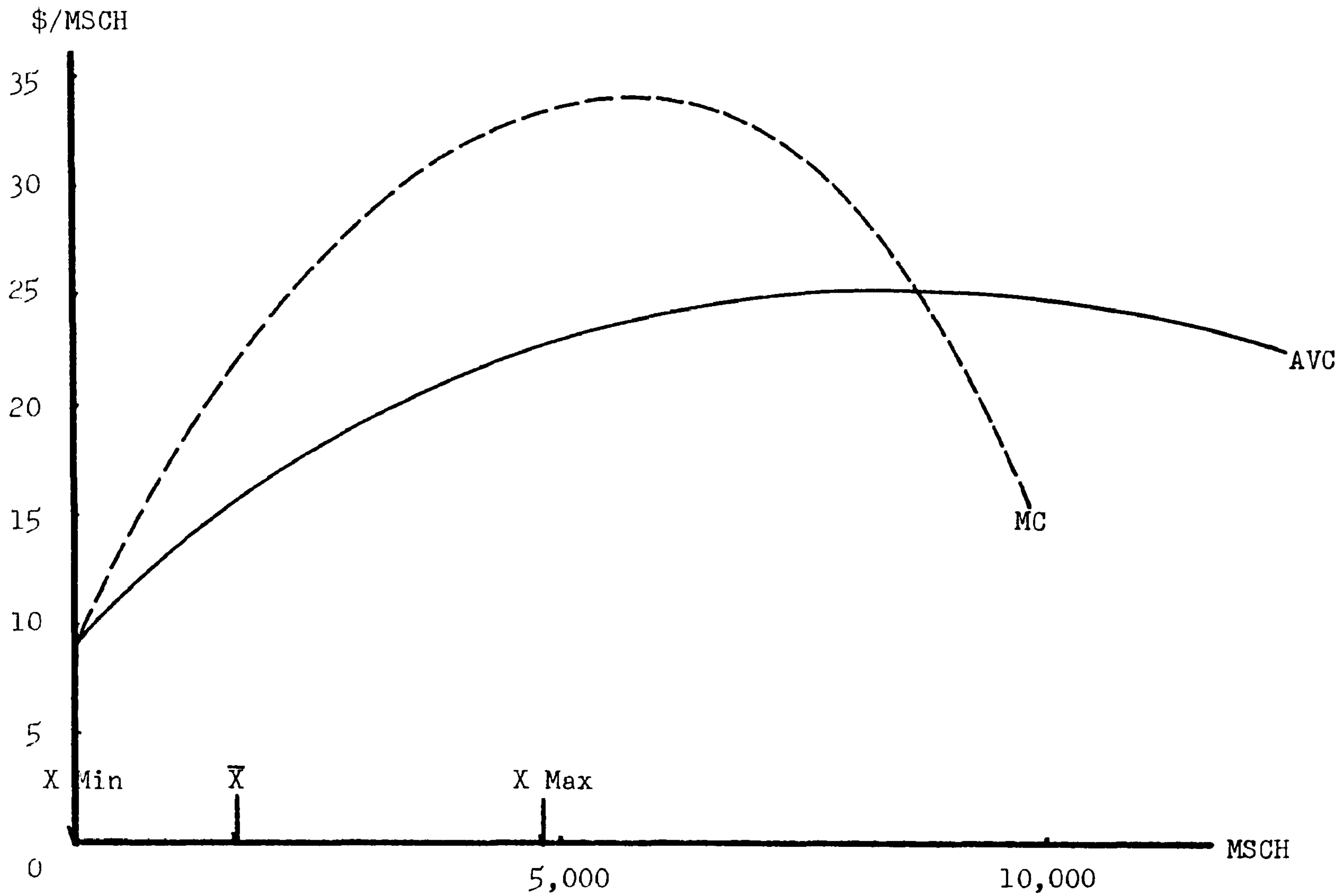

FIGURE 24

SOCIAL SCIENCES MASTERS

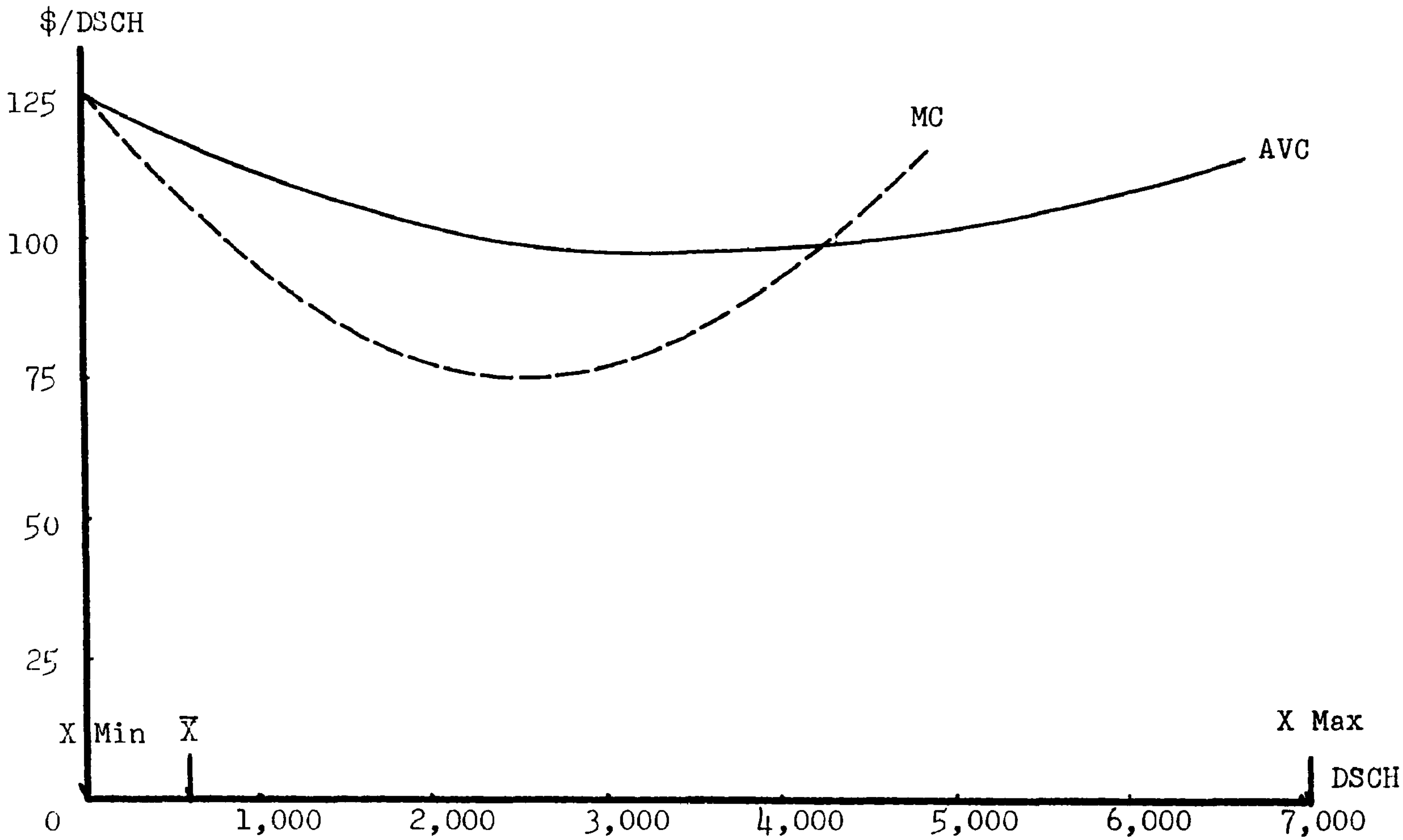

FIGURE 25

SOCIAL SCIENCES DOCTORAL

Squared (-$.1554E-02), Masters times Doctoral (-$.3874E-01), Central Michigan University (-$.5180E05), Lake Superior State College (-$.1678E06), Michigan Technological University (-$.1577E06), Northern Michigan University (-$.7107E05), Oakland University (-$.6583E05), and Saginaw Valley State College (-$.1620E06). Social Sciences and Engineering are the only two disciplines for which all five groups of variables are not significant as noted earlier and in both cases the Square and Cubic groups fail to gain significance at the ten percent level. In both cases the Square group and the Cubic group have one significant variable each, using individual t-tests. For the Social Sciences both were at the Upper Division and for Engineering both were at the Lower Division. Again the signs of the square and cubic terms differ at all levels.

As can be seen in Figures 22 through 25, the Upper Division and Doctoral levels exhibit U-shaped cost curves while the Lower Division and Masters levels show inverted U-shapes. The Social Sciences cost curves are universally in the positive quadrant for the only time.

Summary and Comparisons

Table 14 summarizes the sign and significance results for the six disciplines estimated.

TABLE 14

SIGNS AND SIGNIFICANCE OF THE COEFFICIENTS

Variable	Business	Education	Engineering	Humanities	Nat. Sci.	Soc. Sci.
LD	+	+*	+*	+*	+*	+
UD	+*	+*	+*	+	+	+*
M	-*	+*	+	+*	-*	+
D	+*	+	-	-	+*	+*
LD^2	-	-*	-*	-*	-	+
UD^2	-*	+	-	-*	-*	-*
M^2	-	-*	-	+	+*	+
D^2	-*	+*	+	-	+*	-
LD^3	+	+*	+*	+*	-	-
UD^3	+	-*	+	+*	+	+*
M^3	+	+*	-	-	-*	-
D^3	+*	-	+	-	-*	+
LD x UD	+	-*	+	-	+	+
LD x M	+*	+*	+	+*	-*	+
LD x D	-*	-*	-	-	-	-
UD x M	+*	+*	+	-*	+*	+
UD x D	+	-*	+	-*	+	+*
M x D	-*	+	+	+*	-*	-*
Time	+*	+*	+*	+*	+*	+*
Constant	-	-	-	-*	-*	-

* Significant at the ten percent level

TABLE 14 (Continued)

Variable	Business	Education	Engineering	Humanities	Nat. Sci.	Soc. Sci.
Central Michigan	-*	+		-*	+	-*
Eastern Michigan	-*	+		-*	+	-
Ferris State	-*	+	-	-*	-*	-*
Grand Valley	-*	+		-*	-	-
Lake Superior	-*	+	-	-*	-*	-*
Michigan Tech	-*	+	-	-*	+	-*
Northern Michigan	-*	+		-*	-	-*
Oakland	-*	+	-	-*	+	-*
Saginaw Valley	-*	+		-*	-*	-*
Univ. of Michigan	+*	+*	+*	-	+*	+*
Wayne State	+	+	+	-*	+*	+
Western Michigan	-*	+	+	-	+*	-
Linear Terms	*	*	*	*	*	*
Square Terms	*	*		*	*	
Cubic Terms	*	*		*	*	
Interactions	*	*	*	*	*	*
Institutions	*	*	*	*	*	*

The linear terms at the undergraduate level have universally positive coefficients and eight of the twelve coefficients are significant; and at the graduate level, four estimates are negative with two attaining significance and eight are positive of which five are significant. Fifteen of the twenty-four total linear variables are significant. The fact that two negative estimates reach significance at the graduate level was not expected but can probably be explained by the facts that 1) undergraduate programs are ordinarily large before graduate programs are introduced and there were no purely graduate programs in the sample used and 2) graduate students are clearly used as inputs into the undergraduate educational process. The savings incurred by introducing a graduate program may thus show up either in the interaction term or in any of the other terms since there are few low undergraduate output data points with graduate programs present. Here a portion of the savings realized has shown up in the linear term at the Masters level for the Business Administration and Natural Sciences disciplines. It was expected, a priori that the Natural Science discipline would show one of the strongest levels of savings with the introduction of a graduate program because of the use of graduate assistants in the laboratory for instructional purposes as well as research.

The square terms are negative in sixteen cases and positive in eight with nine significant and negative and three significant and positive. The total of twelve of twenty-four estimates reaching significance again indicates that the square term is important and that there clearly are non-linear relationships extant. At the undergraduate level only two of the eight estimates are positive, neither of which is significant, and seven of the ten negative estimates are significant. At the graduate level on the other hand half of the estimates are positive with three significant and positive and two significant and negative.

The cubic terms have fourteen positive estimates with seven significant and ten negative of which three are significant. At the undergraduate level, three of the twelve estimates are negative while one of the six significant estimates is negative. The graduate level estimates are again five positive and seven negative with two positive and significant and two negative and significant.

As noted earlier the relationship between the square and cubic terms has turned out as expected with the cubic coefficient estimate significantly smaller than the square coefficient and with signs differing for the two terms for a given output level within a discipline in all but four instances of twenty-four. In each instance neither of the terms was significant if signs did not differ.

It should be noted that of the five groupings of variables, only the square and cubic groupings fail to show significance; and that these each fail in two instances: Engineering and the Social Sciences.

The interaction terms show 21 positive estimates, of which eight are significant, and fifteen negative, of which ten are significant. The fact that half of the terms in this category are significant again indicates its importance. For each of the interaction terms except Lower Division times Doctoral, there is a mixture of signs and where more than one discipline shows significance for the variable there is at least one positive and one negative and significant term. At the Lower Division times Doctoral all estimates are negative and two are significant. The only level where there is only one discipline showing significance is Lower Division times Upper Division where Education shows a negative significant relation but four of the six estimates are positive though not significant. There are no very clear consistencies among the six disciplines tested with respect to the interactions found but none were expected.

The Time Trend variable on the other hand shows complete consistency with all estimates positive and significant as was expected. The smallest t-value encountered for this variable was 6.734 for Education and the largest was 18.26 for the Humanities. This variable was very clearly of significance.

The constant term, included for statistical reasons as it was not expected to be significant as a representative of fixed instructional costs, was negative in all disciplines and significant for two. This term will represent the mean effect of left-out variables in addition to its other roles, and the fact that it is universally negative and significant for two of the six disciplines makes interpretation difficult unless the left-out variables are cost saving which may be the case but seems unlikely.

The institutional dummy variables were positive in twenty-six instances, negative in forty instances, and significant in a total of thirty-six cases with twenty-nine significant and negative and seven significant and positive. Of the seven which are significant and positive, the University of Michigan accounts for five; only in one instance did the University of Michigan not have significantly higher costs than Michigan State University and that was for the Humanities where all institutional dummy variables had negative coefficients and ten of the twelve were significant and negative. The only two significant positive institutional dummy variables which were not from the University of Michigan were in the Natural Sciences for Wayne State University and Western Michigan University. The entire picture shown in this research by the institutional dummy variables fits well with expectations regarding the distribution of signs among the disciplines and institutions for this variable.

This section has presented the results of the estimation of the cost function for instruction in higher education for the six disciplines chosen for this study. The model presented in Chapter II has fit well with expectations, has shown each of its terms to be significant for at least one discipline, and has been shown to be highly predictive. The only apparent anomaly is found in the constant term where it was expected that there would be no fixed costs included and where it was expected that the mean effect of any left-out variables would be found; and yet the constant has been found to be universally negative and twice significant and negative.

Tests of Hypotheses

The five hypotheses to be tested in this section fall into two groups: 1) those related to the assumptions necessary in order to use present cost accounting techniques to discover either marginal cost or average variable cost associated with one of the outputs of higher education and 2) those implied by the assumptions of the model used herein and the results of present costing techniques. These two groups will be dealt with separately.

Present Costing Assumptions

As noted earlier, the presently used cost accounting procedures identify the prices of those resources directly used in the production of a given output, add these to find the total cost of an output, and then divide by total output in order to find the average or unit cost of a given output. If the prices of inputs to a given output are a function of the quantity produced of another output, or if the production technique utilized is a function of the presence of a resource implied by the presence of another output, then this procedure does not show the true relation, more correctly it may not show the true relation, among costs. If there are economies or diseconomies of scale in production then the cost figures produced by such a procedure will not also represent marginal costs except in very unusual circumstances though they may be successful in estimating average variable costs. If there is a possibility that within some range of outputs negative marginal costs may be encountered due to the presence of an interaction among the levels of output and therefore that there is a possibility that average variable costs are in reality negative within some ranges which may be encountered, present cost accounting techniques will not discover these negative cost ranges since the technique itself implies positive estimates of unit costs because AVC is by definition here the ratio of two positive quantities.

The above implies that in order to use current cost accounting procedures the following assumptions must be made: 1) there are no interactions among levels of instructional output with respect to costs, 2) there are no economies or diseconomies of scale encountered in the production of instruction, and 3) there are no negative average variable costs encountered within the range of outputs which actually occur. From these assumptions, the following hypotheses in the negative form of the above are to be now tested: 1) the interaction terms of the estimated cost function for instruction in higher education are significant, 2) the nonlinear terms of the estimated cost function are significant, and 3) the average variable costs when calculated using the estimated cost function are not significantly greater than zero in all instances and are significantly less than zero in some instances. None of these results is implied by the assumptions of the model but it is clear that interactions are possible, a nonlinear relationship is possible, and average variable costs may in fact be negative within certain ranges. The results necessary to test hypotheses one and two have already been presented above. The results necessary to test hypothesis three will be developed and presented below. In each case, since no sign or magnitude is implied by the model, two tailed tests will be used at the ten percent level of significance.

Hypothesis One

There were six interaction terms included in the estimate of each of the six disciplinary instructional cost functions. Of the total of thirty-six estimates, eighteen were significant, twenty were positive and sixteen were negative with ten negative and significant and eight positive and significant. The interaction between Lower Division and Upper Division had only one discipline where it was significant, Education; Lower Division times Doctoral was significant for two disciplines, Business and Education; Upper Division times Doctoral was significant for Education, Humanities, and Social Sciences; and the remaining three interaction terms were significant for four disciplines with all reaching significance for Business, Humanities, and Natural Science; Lower Division times Masters and Upper Division times Masters attaining significance for Education; and Masters times Doctoral was significant for Social Science.

From a disciplinary standpoint, individual tests on the variables showed that none were significant for Engineering, two for the Social Sciences, three for the Natural Sciences, four for Business Administration and the Humanities, and five for Education. In no case did a pattern of significant signs emerge for any discipline. Only in the case of Lower Division times Doctoral, where all estimates were negative and two of these were significant, did a variable show any consistency in signs.

The empirical results clearly indicate however that there are statistically significant interactions among levels in the instructional cost function though these do not show a consistent pattern. The inconsistent pattern is not contrary to expectations, however, since the interaction was expected to depend upon instructional technology and acceptable pedagogy which clearly vary among disciplines.

The conclusion reached therefore is that there are in fact interactions among levels which do affect costs.

Hypothesis Two

As analyzed above, the non-linear terms also clearly appear to be significant as twelve of the square terms attain significance and ten of the cubic terms are significant. Unlike the interaction terms, the non-linear terms appear to show a clear pattern among the signs of the estimates although the pattern is not perfect.

The Pattern: Of the twenty-four combinations of instructional level, discipline, and square-cubic terms; in only four cases do the signs of the cubic and square term for the estimates agree: Masters and Doctoral for Engineering, Doctoral for the Humanities, and Lower Division for Natural Sciences. In the other twenty cases, the sign of the square term differs from the sign of the cubic term. None of the eight estimates involved in same signs for both non-linear terms was significant. This differing sign result was expected since economies of scale were expected to disappear as output approached the point where maximum class sizes would be reached for all sections. And diseconomies of scale were expected to disappear as programs became large enough so that faculty suited to higher levels of instruction would be able to specialize at the maximum level of their qualification. These same factors were expected to produce economies of scale, if there were any non-linearities, at the undergraduate level and indeterminate effects at the graduate level; and this, in fact, is what the analysis has shown.

At the undergraduate level, the sign of the square term, the term which determines initial economies or diseconomies of scale, is negative in ten of twelve instances, significant and negative in seven instances, and significant and positive in no cases. At the graduate level on the other hand, the sign of the square term varies, being positive in six cases and negative in six cases with three cases of positive, significant results and two cases of negative, significant results.

These results confirm the existence of significant initial economies and diseconomies of scale in instruction.

The cubic terms show the same regularity of sign at the undergraduate levels with nine of twelve estimates positive and three negative, five estimates positive and significant, and only one negative and significant. The graduate level again shows variability.

It also appears strongly supported that there is a tendency for initial (dis)economies to disappear as programs become larger. There are nine instances in which both the square and cubic term are significant for a level-discipline, and in each case the signs differ between the two terms. Seven of these nine cases show initial economies of scale with five of these seven at the undergraduate level: Lower Division for Education, Engineering and the Humanities, and Upper Division for the Humanities and Social Sciences. There are no cases in which there appear to be initial diseconomies of scale at the undergraduate level where both the square and cubic terms are significant. At the graduate level there are four cases where both terms are significant: Masters in Education and Doctoral in Business Administration show initial economies while Masters and Doctoral in Natural Sciences both show initial diseconomies.

The conclusion reached is that there are significant non-linearities in the cost function, that these tend to be economies of scale at the undergraduate level and may be either economies of scale or diseconomies at the graduate level, and that these non-linearities are extant initially but have a tendency to disappear at higher levels of production.

Hypothesis Three

In order to test the hypothesis that there are negative average variable costs of instruction it will be necessary to provide further information: the average variable cost of the outputs, and the standard error and t-statistic. The Average Variable cost of the four outputs will be defined as follows:

$$AVC_{LD} = \frac{B_1X_1+B_5X_1^2+B_9X_1^3+B_{25}X_1X_2+B_{26}X_1X_3+B_{27}X_1X_4}{X_1}$$

$$AVC_{UD} = \frac{B_2X_2+B_6X_2^2+B_{10}X_2^3+B_{25}X_1X_2+B_{28}X_2X_3+B_{29}X_2X_4}{X_2}$$

$$AVC_{M} = \frac{B_3X_3+B_7X_3^2+B_{11}X_3^3+B_{26}X_1X_3+B_{28}X_2X_3+B_{30}X_3X_4}{X_3}$$

$$AVC_{D} = \frac{B_4X_4+B_8X_4^2+B_{12}X_4^3+B_{27}X_1X_4+B_{29}X_2X_4+B_{30}X_3X_4}{X_4}$$

These are simply those terms in which the output appears, those which can be affected by changes in that output or those which are variable, divided by output at the level in question. These expressions can be simplified by dividing through by the denominator in each case since the denominator appears in each term of the numerator but they are shown in this form in order to clarify the definition. The simplified form would of course not be defined at zero for the output in question.

The average variable costs by level and by discipline computed at the mean output for each student level are found in Table 15 with the standard error and t-value. The point represented by the mean output for each of the four levels is chosen to evaluate the above formulae because these are points that are in the center of the data for each discipline, where confidence should be the greatest regarding the parameter estimates and because a point _must_ be chosen. The standard errors are computed using the standard formula for computing this statistic for a linear combination of random variables and values obtained from the variance covariance matrix of the coefficients. Essentially the output values are assumed fixed at the mean output levels for each of the four outputs and the parameter estimates are treated as random variables with estimated variance and covariance values.

In Table 15, it can be seen that seventeen of the values are significant of the twenty-four and that two are negative and significant and fifteen are positive and significant. The two negative significant values

TABLE 15

AVERAGE VARIABLE COSTS

Discipline Level	Average Cost	Standard Error	t-value
Business Administration			
LD	20.26*	8.61	2.353*
UD	45.50*	17.32	2.627*
M	-7.90	7.81	-1.011
D	491.74*	203.02	2.422*
Education			
LD	8.13	28.07	.2896
UD	20.31*	4.68	4.336*
M	62.45*	9.79	6.382*
D	-9.95	48.96	-.2032
Engineering			
LD	67.96*	37.67	1.804*
UD	51.27*	13.48	3.803*
M	256.65*	95.40	2.690*
D	-51.42	154.09	-.3338
Humanities			
LD	19.68*	1.89	10.413*
UD	-11.39*	6.79	-1.678*
M	207.94*	34.98	5.945*
D	52.70	76.81	.6861

TABLE 15 (Continued)

Discipline Level	Average Cost	Standard Error	t-value
Natural Sciences			
LD	16.42*	4.37	3.757*
UD	37.83*	15.47	2.445*
M	-28.51*	15.87	-1.796*
D	319.64*	54.11	5.907
Social Sciences			
LD	5.30	3.79	1.397
UD	20.55*	5.49	3.742*
M	13.67	15.91	.7552
D	116.4*	36.67	3.174*

* Significant at the ten percent level

occur in the Humanities at the Upper Division and in the Natural Sciences at the Masters level. Of the seven values that fail to attain significance, three are negative and four are positive. Two of these negative non-significant values occur at the Doctoral level, Education and Engineering, and one is at the Masters level, Business Administration. The only surprise here is the negative and significant average variable cost at the Upper Division in the Humanities. This must be taken to indicate that the Humanities departments use a large number of upper division students to aid in the instructional process. It is also possible that teaching upper division students is sufficiently more desirable that lower faculty salaries per student can be paid by departments with upper division programs. The first of these possibilities is made more likely by the relatively high average variable cost encountered for the Humanities at the Masters level. The high Masters level figure, relative to other disciplines, could be explained by the fact that much of the possible student assistance that can be accomplished by non-doctoral level students is already done by upper division students before masters programs are introduced. Even if after masters programs are introduced and these student assistance duties are taken over by the graduate students from the upper division students, much less would be saved in this way than would be saved if the graduate assistant were replacing a faculty member; and this option may actually be more expensive but necessary in order to recruit graduate students.[20] This would also be consistent with the relatively low estimate of average cost at the Doctoral level. The second of the above possible explanations seems relatively unlikely but possible. There is of course the third possibility that this is not really a parameter that is less than zero.

Nine of the average variable cost estimates are not significantly greater than zero and two of these are both negative and significant. This indicates that it is certainly possible that some negative average variable costs may be encountered at the mean output levels, but it certainly cannot be considered to be conclusive evidence. The evidence is not much stronger if the graduate level values alone are examined. The graduate level is the level at which it would be expected that the effects which may lead to negative average variable costs would be most likely to occur. Although four of the twelve estimates are negative and one of these is significant, the strongest evidence for the possibility of negative average variable costs occurs in the Natural Sciences. Here it would be expected *a priori* that the cost saving effects of a graduate program would be the greatest due to the extensive faculty time required in laboratories which can be replaced by high quality graduate students at much lower cost. And the masters level coefficient is significant and negative.

With respect to this hypothesis, the conclusions reached must be more cautious than those of the first two hypotheses, however. It does appear that negative average variable cost estimates are clearly not out of the question. Therefore, some consideration should be given to a costing technique which aims to estimate average costs but does not eliminate the possibility of negative average cost results by definition.

Model Generated Hypotheses

Two hypotheses were generated from the model and presently accepted cost data. These are: 1) Marginal costs are universally greater than zero and 2) marginal costs increase with student level. The tests of both of these hypotheses require additional data.

Positive Marginal Costs

Table 16 presents the marginal cost values as evaluated again at the mean output value for each output. The marginal cost at each level is computed by taking the first partial derivative with respect to each level of output respectively which results in the following:

TABLE 16

MARGINAL COSTS

Discipline Level	Marginal Cost	Standard Error	t-value
Business Administration			
LD	16.31*	5.01	3.253*
UD	24.75	34.96	.7079
M	-15.03	9.47	-1.587
D	188.06	124.44	1.471
Education			
LD	-12.45	23.63	.5269
UD	21.53*	3.77	5.713*
M	34.64*	5.90	5.874*
D	46.37	43.88	1.057
Engineering			
LD	39.46*	15.78	2.520*
UD	40.70*	6.99	5.818*
M	177.52*	57.86	3.068*
D	19.29	94.81	.2034
Humanities			
LD	15.43*	1.68	9.205*
UD	-15.21*	3.77	-4.031*
M	198.86*	22.70	8.760*
D	37.24	66.16	.5629

TABLE 16 (Continued)

Discipline Level	Marginal Cost	Standard Error	t-value
Natural Sciences			
LD	13.36*	2.070	6.453*
UD	12.82	8.68	1.478
M	8.35	23.66	.3529
D	380.96*	36.54	10.427*
Social Sciences			
LD	6.86*	2.10	3.260*
UD	14.87*	3.42	4.342
M	17.44	10.99	1.586
D	108.49*	28.16	3.853*

* Significant at the ten percent level

$$MC_{LD} = B_1+2B_5X_1+3B_9X_1^2+B_{25}X_2+B_{26}X_3+B_{27}X_4$$

$$MC_{UD} = B_2+2B_6X_2+3B_{10}X_2^2+B_{25}X_1+B_{28}X_3+B_{29}X_4$$

$$MC_M = B_3+2B_7X_3+3B_{11}X_3^2+B_{26}X_1+B_{28}X_2+B_{30}X_4$$

$$MC_D = B_4+2B_8X_4+3B_{12}X_4^2+B_{27}X_1+B_{29}X_2+B_{30}X_3$$

The table presents the marginal cost figures in the first column, the standard error in the second column and the t-value in the third column. Again the standard error is computed using the standard formula for linear combinations of random variables using the variance covariance matrix of the coefficients.

Comparing the results found in Table 16 with those in Table 15, it should be noted that the results are the same with respect to significance and sign with the following exceptions: Upper Division and Masters level average costs are both significant for Business Administration but the marginal cost estimates, while both positive again, do not attain significance at the ten percent level; there is a sign shift in Education at the Lower Division and Doctoral levels although none of these estimates is significant; a sign shift also takes place at the Doctoral level in Engineering; in the Natural Sciences the Upper Division significance is lost in the marginal cost table and a negative significant estimate of marginal cost at the Masters level is positive and non-significant for Marginal cost; for the Social Sciences the only difference lies in the gaining of significance at the lower division.

Two AVC estimates were negative and significant but only one of these, Humanities at the Upper Division remains negative and significant as the focus changes from AVC to MC. And five negative estimates of AVC can be compared to only three for MC. Once again there is evidence of the possibility of negative marginal costs but the evidence is certainly not conclusive.

Marginal Costs Increase with Student Level

The data necessary to test this hypothesis are found in Table 17. These are presented such that the relevant differences between marginal costs for a discipline as student level increases are shown in column one, the relevant standard error is shown in column two, and the t-value is shown in column three. The movements in marginal costs are measured in the three steps: 1) Lower Division to Upper Division, 2) Upper Division to Masters level, and 3) Masters level to Doctoral level. These were chosen because there has been clear evidence that costs increase from one level to another for averaged departments and for individual departments with very few exceptions.

The results show that of the eighteen comparisons,

TABLE 17

DIFFERENCES BETWEEN MARGINAL COSTS

Discipline Level Difference	Difference	Standard Error	t-value
Business Administration			
UD - LD	8.44	36.14	.2335
M - UD	-39.78	34.97	-1.138
D - M	251.93	121.44	1.631
Education			
UD - LD	33.98	24.62	1.380
M - UD	13.11	8.43	1.554
D - M	9.73	44.35	.2194
Engineering			
UD - LD	1.23	19.33	.0636
M - UD	136.81*	61.44	2.227*
D - M	-158.23*	60.57	-2.612*
Humanities			
UD - LD	-30.64*	5.51	-5.561
M - UD	214.15*	20.91	10.24*
D - M	-166.58*	77.74	2.078*
Natural Sciences			
UD - LD	-.54	9.20	-.0587
M - UD	-4.57	53.49	-.0854
D - M	372.61*	40.43	9.216*

TABLE 17 (Continued)

Discipline Level Difference	Difference	Standard Error	t-value
Social Sciences			
UD - LD	8.01	6.41	1.250
M - UD	2.57	9.75	.2636
D - M	91.05*	30.03	3.032*

* Significant at the ten percent level

seven are significant and, of these, four are positive and three are negative. Of the eleven estimates which do not reach significance, eight are positive and three are negative. Only two of the disciplines show consistent rises in marginal costs as student level rises: Education and Social Science. The individual increases for these two disciplines are not significant except for the Masters to Doctoral increase for the Social Sciences if two-tailed tests are used. The use of one-tailed tests which should have been implied a priori by former evidence would result in two of the Education differences and one Business Administration difference attaining significance. The fact that so many of the estimates are significant and negative if two-tailed tests are used seems to make the use of a one-tailed test out of the question. One-tailed tests would affect only three of the estimates: two in Education and one in Business Administration.

In the case of the Natural Sciences, only the positive shift in costs from the Masters to Doctoral level is significant. For Engineering, two of the differences are significant with one negative and one positive in each case. The Humanities show three significant differences with two negative and one positive.

There is only one discipline which shows a significant difference at the Lower Division to Upper Division level, Humanities, where this difference is negative. The

Upper Division to Masters level is significant for two disciplines: positive for both Engineering and the Humanities. The Masters to Doctoral difference is significant in four of the six disciplines but the sign is positive in two cases and negative in two. The only disciplines where the Masters to Doctoral difference is not significant are Business Administration and Education where the estimates are both positive.

The conclusion reached is that there is clear evidence that precludes the acceptance of the hypothesis that all marginal costs increase with increases in student level at least at mean output levels. A one-tailed test would show positive and significant results for eight of the eighteen possible cases, but the large number of negative estimates and three cases of two-tailed significant negative results makes acceptance of the hypothesis impossible.

Summary

It is clear from the results of the estimation procedure that the cost function estimated yields significant predictive power; however, the tests of the two hypotheses implied by the model and expectations of decision makers with reference to relative costs based on previously available data do not yield supportive results. This is consistent with the results of the checks on the assumptions under which the previously available data were produced. In two cases, the assumptions were rejected and in the third, there was significant evidence to reject. The apparent non-validity of the assumptions under which previous data were produced apparently led to inaccurate cost estimates which in turn precluded decision makers from maximizing welfare as indicated by the results of the tests of the final two hypotheses. Unrealistic assumptions do not necessarily imply results which do not correspond to reality; but in the case of the costing procedure used to estimate costs of instruction in the State of Michigan at least, these unrealistic assumptions seem to have led to conclusions which may have led to non-optimal allocation of resources in at least the two disciplines where marginal costs have significant declines as student level increases: Engineering and the Humanities. The assumptions that outputs at the various student levels are independent, that there are no (dis)economies of scale and that negative costs are not possible have been unrealistic enough to result in possible nonattainment of the welfare maximum. Thus there have been arguments presented which should demonstrate the inadequacy of present procedures and the inaccuracy of present conceptions of the cost relationship to those who judge a model on the basis of the realism of the assumptions and to those who judge a model on the basis of the validity of the results.

Footnotes Chapter III

18. Unit Cost Study.
19. The t-values are high enough that such questions do not arise. If this were not the case, one-tail tests would clearly be appropriate.
20. It is assumed here that graduate students would be deemed to provide superior service though undergraduates would suffice.

CHAPTER IV

Summary and Conclusions

A model of the productive process in higher education was presented in Chapter II which generated the nature of the total cost function for a department. The hypothesized form of the total cost function was then estimated and tested in Chapter III.

The results presented in Chapter III clearly show that this model has significant predictive power. All of the variables are significant in at least one of the six disciplines examined as can be seen in Table 3.8. In general there is not very much consistency among the disciplines tested except in the following ways: 1) in each case the time trend is positive and significant, 2) the estimates of the linear terms are all positive and many are significant at the undergraduate level, 3) some non-linearities are present for each discipline with a strong tendency toward economies of scale at the undergraduate level and a mixture of economies and diseconomies at the graduate level, 4) all non-linearities have a tendency to disappear at higher levels of output where individual coefficients are significant and in all but a few cases where the variables do not attain significance, 5) each of the disciplines except Engineering shows at least two significant interactions among the student levels of instructional output but here there is no clear pattern of regularity among the disciplines with reference to signs, 6) each of the institutional dummy variables is significant in at least two of the disciplines although in the cases of Education and Engineering, only the University of Michigan shows as being significant; the signs of the significant variables correcting for institutional differences are as expected, positive for the University of Michigan and negative for other institutions with the exception of two cases, Wayne State University and Western Michigan University in the case of the Natural Sciences, and 7) in each case in which the groups of variables were tested they were found significant with the exception of the square and cubic terms in the cases of Engineering and Social Sciences where in each case there was evidence of non-linearity at one level in both the square and cubic terms.

The tests of the hypotheses generated by the assumptions necessary for the use of present costing procedures clearly demonstrate that these assumptions are not met and the hypotheses based upon the results of the present costing procedures and the model of Chapter II clearly show that the results of the procedures have been erroneous and have led to failure to maximize welfare unless the assumptions under which the model of Chapter II is built are not met.

The policy implications of these results are potentially significant. These include the desirability of maintaining a data system which not only records the instructional output of the system of higher education by department but also records all of the output in a systematic and consistent manner. There are clearly difficulties involved in maintaining such information; however, if decisions are to be made which will maximize the benefit of the activities of the system of higher education provided by the various governmental agencies, such data are mandatory. One of the greatest drawbacks of the present study was the inability to account in a quantitative manner for research and public service produced as a result of the expenditures in the instructional budget. It is felt that had accurate data been available on these outputs the results involving negative marginal and average variable costs would have been clearer since it is expected that both research and public service activity would be greatest at graduate level institutions where it would have a tendency to lower the costs of graduate level output. The fact that the constant term was found to be negative for all disciplines and significant for two disciplines, may indicate that these left-out variables--they were included as qualitative variables--may have had the opposite effect of reducing costs and increasing the coefficients of the instructional outputs and particularly at the graduate level.

There may well be arguments now for increasing the size of the average department in all disciplines since wherever economies of scale were present, almost universally at the undergraduate level, these were not yet used up at the average departmental size. This implication is not necessary, however, because there are other considerations affecting community welfare with respect to location of educational plant and costs in terms of foregone income and travel time, etc.

It seems clear that upper division programs in the Humanities should be encouraged wherever there is a demand for them since upper division programs seem to lower total costs. The same can be said for masters programs in the Natural Sciences. If in fact instructional costs can be saved at the same time that additional opportunities can be offered to a local community, it would seem to be non-rational if such services were not provided if there were a demand. The argument in the case of the Natural Sciences may not be as strong as in the case of the Humanities since there may well be expenses incurred in the production of specialized laboratory facilities for masters level programs in certain departments which would more than outweigh the savings realized in instruction. Unfortunately the cost of such specialized instructional facilities is not included in the instructional budget. Since some areas in the Physical Sciences are experiencing a slackening in demand for graduate level programs, the argument for eliminating these was stronger than it is now that the possibility of net savings as a result of masters level programs has been shown. Each department is unique and must be viewed in that way: 1) each department will have a different mix of faculty by rank, 2) each department will have a different mix of tenured and non-tenured faculty, 3) each department has a different set of specialized physical facilities available to it, etc.

The analysis of both marginal and average costs and the differentials in marginal costs may have other implications with regard to the mix of programs by level. It is clear in the case of negative costs that programs should be encouraged, and it is equally clear that if decision makers felt the mix of outputs to be optimal under the assumption that costs increase with student level these same decision makers should now feel that the mix of outputs is non-optimal when it is seen that the relative costs may well not be as they were previously perceived. In the case of Business Administration disciplines, it would seem more likely that masters level programs would be encouraged when it is noted that masters level programs are potentially less expensive than upper division programs in the same discipline. The same should be true of doctoral level programs in Engineering and the Humanities. If at present output the marginal student in these disciplines at the doctoral level was thought to have a value in excess of the marginal masters student and it is now discovered that the doctoral student is much less expensive than the masters student, only two responses seem appropriate: 1) increase doctoral output from present levels, or 2) decrease masters level output.

So changes in departmental size, departmental location, and the mix of output by student level may well be implied by this present research.

Although there are clearly limitations on the results which call for further research on the topic of costs in higher education, this thesis is the first to use economic analysis to explain and measure costs in institutions of higher education which has allowed for the possibilities of (dis)economies of scale, interactions among the levels of student output and negative average variable and marginal costs using a weighted regression technique. It also shows that economic techniques and the assumption of rational behavior can yield useful results in yet another area of investigation.

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WORKS CITED

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