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ABSTRACT

Classical multiple regression was compared with Bayesian m-group regression, complete with cross-validation. The setting was a post-developmental studies situation in a comprehensive community college. A secondary purpose of the study was to incorporate an advisor prediction of grade point average (GPA) as input into both regression procedures. The reliability and predictive validity of the advisor predictions were both investigated. One major strength of the study was the inclusion of variables measuring progress during developmental studies. Predictions based solely on data available prior to developmental studies would invariably predict failure because it is those variables which suggested a need for developmental studies in the first place. A second major strength of this study was the inclusion of an advisor prediction as a variable in both regression methods. This inclusion maintained comparability between methods while allowing the inclusion of both "hard" and "soft" data. The criterion variable in the study was first-quarter GPA in the student's chosen curriculum, after the student had completed developmental studies. (Author/CTM)

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An Application of Bayesian M-Group Regression to Developmental Studies Programs in a Community College

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INTRODUCTION

Developmental studies programs have been one of the major identifying features of the community colleges in the United States in the twentieth century. These programs were deemed necessary by the general availability of the "open-door" policy on admissions at these "people's colleges." Since many of the students who were attracted to these new colleges were under-prepared by traditional academic standards, the community colleges undertook an ever-increasing role in remediating the deficiencies of these non-traditional students. "It was in the community college that postsecondary efforts at remedial education became widespread two decades ago." (Roueche and Snow, 1977, p. 4) Although many titles were assigned to the new programs, the term "developmental studies" seems to have become somewhat standard.

Since the open door policy precluded any major emphasis on admissions, the guidance of prospective students into suitable curricula has taken on extreme importance. As Novick (1970, p. 1) has said, "Decisions of consequence for each students center largely around the choice of program of study." Thus, in addition to developmental studies, the emphasis on guidance has been another identifying feature of the community colleges. Many counselors in the community colleges have been concerned that non-traditional students would be unsuccessful in many curricula. In fact, several books and articles in the early 1970's expressed the fear that the open door has become simply a revolving door. (Moore, 1970, 1971, 1976; Roueche and Kirk, 1974; Roueche and Snow, 1977).

To prevent the open door from becoming a revolving door, especially for developmental students, the community college must give major attention to the counseling of students during and after completion of developmental studies. (Bushnell, 1973, pp. 108-114) Often the student never sees a counselor during the course of his studies. As a result, the professional help which could have been offered is never made available. In many cases it is left to the classroom instructor to assist the developmental students in their choice of curriculum. Thus, the nontraditional student, perhaps with some faculty assistance, has had to apply whatever common-sense or rumor-mill data he could locate in his search for a suitable curriculum in which he might succeed.

Even if counseling were available for developmental students, the problem of curriculum selection has been viewed primarily as a selection problem for admissions officers at universities rather than as a guidance problem for counselors and students at community colleges. Given the difficulties of curriculum selection after developmental studies at the community colleges, it seems that admissions procedures could and should be applied in this parallel situation. (Novick and Jackson, 1974a, p. 81) Henriksen (1973) applied such procedures to various curricula at a single institution. His premise was that the results of "admissions" procedures should be for the benefit of the student making the selection of major field, rather than the admissions officer comparing potential students for selective admissions.

Present Status of the Problem

Historically, the admissions problem has centered on predicting grade point average (GPA) for the first term or first year of college study using multiple regression procedures. The predictor variables have almost always included high-school grades and the scores obtained on standardized tests. Other measures of the student have also been used, with differing degrees of success. Some of the more unusual predictor variables in recent studies were marital status of family, position in family, and number of siblings (Chase and Johnson, 1977); geographic area (Adams, et al, 1976); and parochial or non-parochial school (Astin, 1971).

The purpose of the more recent studies has been to aid the potential student in his selection of curriculum within a college as well as in his selection of college. This version of the classic multiple regression admissions procedure has the advantage of giving the student the results of the analysis so that he may then input those results into his personal decision-making process. For the new students in developmental studies in the community colleges, however, the traditional analyses would invariably forecast failure because the predictor variables used in the analysis are the very same variables which relegated the student to developmental studies in the first place. (Moore, 1970, p. 7) Consequently, it seems reasonable that the prediction should not be prepared until all the relevant data are available. Data measuring progress in developmental studies and the resulting higher capabilities of the student should be included. Given the premise that developmental studies can help at least some of the non-traditional students, then it would be premature to predict curriculum success without taking the developmental studies process into account.

Problem Statement

Two methods have traditionally been used in selecting an appropriate curriculum and/or predicting success in that curriculum: classical statistical prediction and informal counselor prediction. Classical statistical prediction uses multiple regression to develop a prediction equation which is applied in exactly the same way to each student's data, while informal counselor prediction allows a counselor to incorporate beliefs and impressions along with data in predicting separately for each student. The classical statistical prediction methods which utilize multiple regression have three basic weaknesses for the kind of application under consideration. First there is concern for the special individuals against whom the prediction is biased. As Novick and Jackson (1970, p. 461) point out:

> When society adopts the formal classification model, it is satisfied because assignments, on the average, are then good. The student, however, is unconcerned with such average good. If he perceives that he belongs to some subgroup for which, on the average, poor assignment decisions are made, it will not comfort him to know that the system works well for almost everybody else.

Second, sample size would seldom be large enough to ensure validity in classical statistical prediction models. Kerlinger and Pedhazur (1973, p. 442) proposed that over 100, and preferably over 200, are needed to protect the validity of predictions. Samples of this size are usually impossible to all but the very largest community colleges. Third, the users of a classical statistical prediction model would often not understand the model well enough to apply it properly. Counselors, advisors, and especially the students themselves are seldom adept at interpreting the output of statistical models.

The informal counselor prediction model allows, and even encourages, consideration of unique characteristics of individuals whose statistical description is not an accurate picture of potential. This model also has no requirement for minimum sample size and no background requirement for proper interpretation. However, the counselor predictions tend to lack reliability and cannot be adequately documented. As Houston (1976) points out, counselor prediction models frequently fail to produce consistent, predictable, and dependable results and cannot always identify what has really been measured.

A hybrid model that would utilize both counselor input and statistical analysis would be more appropriate than either of the two pure models. (Houston, 1976, p. 6) Such a model is available in Bayesian m-group regression, which was developed by M. R. Novich and his associates based on a mathematical framework developed by D. V. Lindley. Bayesian m-group regression uses an application of Bayes' Theorem to separate the statistical analysis by groups to the extent allowed by the data in each group. (Novick and Jackson, 1974a, p. 79) This is equivalent to an informal counselor input which recognized difference between curricula. However, Houston (1976, p. 103) recommended that the Bayesian model be extended "with the inputs of certain counselors' evaluations as independent variables."

Purpose of the Study

The purpose of the study was to compare classical multiple regression with Bayesian m-group regression, complete with cross-validation of both methods. Novick and Jackson (1974a, p. 77), Houston (1976, p. 104), Hinkle and Houston (1977), Henriksen (1973, p. 63), and Kerlinger and Pedhazur (1973, pp. 282-284) have stressed a need for additional cross-validation studies in order to check shrinkage of the multiple correlation obtained in regression applications. The context of the study was to predict first-quarter GPA for post-developmental students in various curricula in a comprehensive community college. In addition to high school data and standardized test scores, each student would also have data representing his level of success in developmental studies.

A secondary purpose of the study was to incorporate a counselor prediction of each student's GPA. The inclusion of these input data into both the classical multiple regression and the Bayesian m-group regression was specifically suggested by Houston (1976, p. 103) and Hinkle and Houston (1977) and also meets the general suggestion of Novick and Jackson (1970, p. 89). In the present study, a counselor prediction was incorporated into both prediction methods and the reliability and predictive validity of the counselor predictions were investigated.

Subjects

Two groups of subjects were needed for this study. The first group, from which the prediction equations were developed, were those students who completed developmental studies and then finished at least one-quarter of their chosen curriculum at a comprehensive community college between Fall, 1974, and Spring, 1978. This group was called the screening group. The second group, upon which the prediction equations were applied, were those post-developmental students who completed one quarter of their chosen curriculum at the community college during Summer or Fall, 1978. This group was called the calibration group. These two groups were necessary for cross-validation.

Regression Analyses

Bayesian m-group regression was performed with a FORTRAN program developed by Shigemasu (1976) entitled "Bayesian M-Group Regression Analysis with Identical Beta." An assumption of equal slopes across m-groups was incorporated by Shigemasu (1976) as a simplification of Bayesian m-group regression. This assumption says that the regression coefficients of each predictor variable in the regression equations are independent of groups. This means that the impact of any variable on GPA (for example) is the same, or very nearly the same, in each group. The only regression parameter allowed to change across groups is the intercept, the regression constant. Shigemasu states his belief that "this equal-slope model is a realistic, reasonable specification for many applications in academic prediction." (1976, p. 158) The two primary advantages to this equal-slope assumption are that all data from all groups may be used in estimating the slopes (likely increasing the precsision of estimation) and that computation time is significantly reduced (likely increasing the availability of Bayesian methods). (Shigemasu, 1976, p. 158)

Classical multiple regression analysis was performed with the REGRESSION subprogram of the Statistical Package for the Social Sciences (for OS/360, Version M, Release 8.0, January, 1979) (Nie et al, 1975). The final regression model was determined by using two backward deletion methods (Hinkle, 1979, p. 405). The first of these methods was to compare the restricted regression model following the systematic deletion of a variable to the original full model. The second method involved comparing the restricted model to the full model of the previous step. The rationale for using the two methods is that "it would be possible to delete variables that singly do not make a significant difference, but collectively account for a significant portion of the variance" (Hinkle, 1979, p. 405).

RESULTS

The final regression model included the following predictor variables:

1. Sex of the respondent (SEX)
2. Curriculum change during developmental studies (Yes or No) (CHANGE)
3. Comparative Guidance and Placement (CGP) Test
    a. Reading (READ)
    b. Sentences (SENT)
    c. Mathematics (MATH)
4. Counselor Prediction (PRED)

Cross-Validation

After completion of classical multiple regression and Bayesian regression analyses on the screening group (N = 399), the two prediction equations were applied to the calibration group (N = 45). The subjects assigned to the calibration group were those students who completed one quarter post-Developmental during Summer or Fall, 1978. Using the last group of subjects as the calibration group mirrors the real-life application of GPA prediction studies, i.e., last year's students' scores generate a prediction model which is applied to this year's students.

Since the classical regression equation is a least-squares best fit on screening data, its application to calibration cases is expected to show a decreased R. In this study, multiply R^2 shrank from 0.281 on screening to 0.271 on calibration. On the other hand, since the Bayesian regression equation adjusts coefficients and intercepts toward the grand mean values, Bayesian R^2 values can be expected to exhibit more stability when applied to calibration cases. In this study, Bayesian R^2 actually increased from 0.275 on screening to 0.279 on calibration.

Comparing Multiple Regression with Bayesian Regression

With the assumption of equal slopes across m-groups but different intercepts from each group, classical multiple regression analysis was performed on screening group data. The criterion variable, first quarter curriculum GPA, was regressed on the total set of predictor variables, which included six of the original predictor variables and the five dummy variables. Regression coefficients (b) and beta-coefficents for the least-squares hyperplane are given in Table 1. In addition to b and beta-coefficients, Table 1 also reports an R^2 value of 0.281 for classical multiple regression with equal slopes.

With the FORTRAN program developed by Shigemasu, taking the mulitple regression slopes and intercepts as initial values, a set of

Bayesian slopes and intercepts was developed for the screening group data. Coefficients for the Bayesian regression hyperplane are also given in Table 1. Also given is R^2 of 0.275 for Bayesian m-group regression with equal slopes.

Coefficients for predictor variables are quite similar in both regression models. However, for each dummy variable, the Bayesian regression coefficient is closer to zero than the multiple regression coefficient. It should be noted that these coefficients for the dummy variables display the Bayesian assumption: intercepts for m-groups should be modified in the direction of the grand mean intercept. According to Lindley and Smith (1972, p. 16), they "tend to be 'shrunk' towards a common value."

To compare the results of multiple regression with the results of Bayesian regression either in the screening group or in the calibration group, a dependent t-test for correlated samples was used (Ferguson, 1976, p. 185). These data indicate (see Table 2) that R^2 values for the screening group are not significantly different. With a classical R^2 of 0.281 and a Bayesian R^2 of 0.275, the t-value is 0.92, with an associated probability of 0.356. Similarly, for the calibration group, the classical R^2 of 0.271 and the Bayesian R^2 of 0.279 are not significantly different ($t = 0.23$, $p = 0.816$).

Mean Errors; Mean Absolute Errors; Mean Squared Errors

In addition to the test of R^2 to compare Bayesian m-group regression with classical multiple regression, tests were performed on mean-error-loss, absolute-error-loss, and squared-error-loss (Novick and Jackson, 1974b). Each of these tests begins by calculating the error of prediction for each student, predicted GPA minus actual GPA. Mean-error-loss simply computes the mean of these errors across all students. Absolute-error-loss computes the mean of the absolute values of the errors, and squared-error-loss computes the mean of the squares of the errors. All statistical comparisons were performed with dependent t-tests (Ferguson, 1976, page 180). It is most interesting to note in Table 2 that none of the comparisons showed any statistically significant difference between classical multiple regression and Bayesian m-group regression.

Predictive Validity of Advisor Predictions

Two methods were used to determine the predictive validity of adviser predictions in this study. In the first method, the product-moment correlation between committee prediction (PRED) and actual GPA, for all subjects in both screening and calibration groups (N = 444), was found to be 0.457. The second method involved the inclusion of advisor predictions to determine whether the magnitude of the multiple correlation coefficient would increase in either regression method. In classical multiple regression, the final model resulted in an R^2 of 0.281. The same model with PRED deleted had an R^2 of 0.258. This statistically significant difference in R^2 demonstrated the predictive validity of advisor predictions. In addition, PRED had the largest standardized regression coefficient (beta), a measure of relative level of contribution, of any of the predictor variables in the study. Thus, not only did the inclusion of PRED increase R^2, but also PRED was the largest contributor to the final regression model.

Limitations of the Study

There were several limitations in this study. The first, and probably most critical, was the use of Shigemasu's equal-slope assumption. Use of the general Bayesian regression method without this assumption may have produced different results, because it would have allowed for different slopes for the same variable in different m-groups. If the "true" relationship between a given variable and GPA changes across the m-groups, then this equal-slope assumption would be tenuous, and the predictive validity of the regression equation would be automatically lower than it would have been using a general Bayesian m-group regression. Nevertheless, Shigemasu (1976, p. 158) justified his assumption and successfully tested it. In addition, the size of the groups in the present study was insufficient for a general Bayesian m-group regression.

Sample size was a second limitation in the present study, in that there were 399 students in the screening group and 45 students in the calibration group. Since the most liberal requirement (Gorsuch, 1974, p. 296) calls for five times as many students as variables, there was no possible justification for retaining all 17 predictor variables. Consequently, the predicative validity of the final regression models in the present study was limited by the number of permissable variables.

A third limitation was the method of grouping curricula. Six m-groups were established in the present study based on similarities in curriculum courses and on the level of mathematics required in developmental studies prior to curriculum entry. Although such a grouping can be logically defended, there are still some differences within groups which could threaten validity of GPA predictions.

A fourth limitation in this study was the use of "blind" data for the counselor prediction. Even though their predictions proved to be quite reliable in predicting first-quarter GPA, questions still remain about how much better, or worse, the counselor predictions could have been following face-to-face contact with each student.

Strengths of This Study

One major strength of this study was the inclusion of variables measuring progress during developmental studies. Predictions based solely on data available prior to developmental studies would invariably predict failure because it is those variables which suggested a need for developmental studies in the first place. (Moore, 1970, p. 7)

A second major strength of this study was the inclusion of an counselor prediction as a variable in both regression methods. This inclusion maintained comparability between methods while allowing the inclusion of both "hard" and "soft" data. This is the sort of compromise needed between classical statistical models and counseling models. (Houston, 1976, p. 6)

TABLE 1

Coefficients of Regression Equations

	Classical		Bayesian	
variable	b	beta	b	beta
PRED	0.350	0.204	0.369	0.215
MATH	0.018	0.135	0.018	0.135
READ	0.012	0.121	0.012	0.125
SENT	0.012	0.112	0.012	0.108
CHANGE	-0.243	-0.106	-0.250	-0.110
SEX	0.148	0.068	0.163	0.075
DUMA	-0.006	-0.002	-0.003	-0.001
DUMB	0.077	0.026	0.022	0.007
DUMC	-0.010	-0.003	-0.002	-0.001
DUMD	-0.329	-0.077	-0.044	-0.010
DUME	0.114	0.048	0.041	0.017
constant	-0.631	0	-0.678	0
R^2	0.281		0.275	

TABLE 2

CORRELATION COEFFICIENTS

MEAN ERRORS

MEAN ABSOLUTE ERRORS

MEAN SQUARED ERRORS

	Classical		Bayesian	t	p
	0.281	R^2	0.275	0.92	0.356
Screening Group N = 399	0.000	mean error	0.000	0.09	0.931
	0.725	mean ab. error	0.729	0.84	0.403
	0.836	mean sq. error	0.844	0.80	0.425
	0.271	R^2	0.279	0.23	0.816
Calibration Group N = 45	-0.014	mean error	-0.048	1.78	0.083
	0.734	mean ab. error	0.714	1.05	0.299
	0.919	Mean sq. error	0.908	0.19	0.848

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