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RISK ANALYSIS IN ECONOMICS:
AN APPLICATION TO UNIVERSITY FINANCES

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Abstract of

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Although the theory of decision making under uncertainty has been extensively studied for a half-century, applications to business applications are relatively rare. This study frames a systematic risk analysis and applies the technique to the finances of private colleges and universities. It begins by constructing budgets for colleges and universities and then analyzes the major economic factors affecting those budgets. It estimates the variability (or unpredictability) associated with each major external variables from historical data and from economic forecasts. The study finds that government-spending risks outweigh all other external influences, with the next largest risks coming from the stock market, interest rates, inflation, and wage trends. The paper concludes by suggesting that institutions consider the implications of exogenous uncertainties other than financial markets on their economic health. It considers the development of general "spending rules" (which would be extensions of conventional "endowment spending rules") to take into account all exogenous uncertainties.

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RISK ANALYSIS IN ECONOMICS:
AN APPLICATION TO UNIVERSITY FINANCES[1]

Although the theory of decision making under uncertainty has been extensively studied for a half-century, actual applications of the theory are relatively rare. The standard theory of decision making under uncertainty requires the specification of a utility function as well as a careful enumeration of the payoffs and probabilities of different states of the world.[2] Since managers seldom have the time or temperament to undertake a systematic decision-theoretic analysis, it is not surprising to find that organizations are often startled at the occurrence of moderately likely events.

This paper is an attempt to frame one part of a systematic risk analysis -- the part that assesses the probabilities of different states of the world. Although the technique applied is relatively general, the application is to a specific problem -- measuring the risks to the finances of private colleges and universities. No one who has studied the finances of the academy doubts that there is an academic business cycle similar to the conventional business cycle. But there has been no attempt to measure the extent of an

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[1] An early version of this study was presented to a conference sponsored by the Forum for College Financing Alternatives and to the NBER Summer Workshop on the Economics of Higher Education. I am grateful for helpful comments by Richard Anderson, Alvin Klevorick, William Massy, and the participants in those conferences. All opinions and errors are the author's.

[2] See Raiffa [1968] for a careful analysis.

academic business cycle, along with the potential risks faced by colleges and universities. The methodology devised here is applied to this specific question.

Before launching into the discussion, it may be helpful to explain why a risk analysis is a useful exercise. Those who study human behavior have found a striking regularity -- people systematically underestimate the degree of uncertainty that they face.[3] For example, when people are asked to give both their opinion and their subjective degree of uncertainty about "encyclopedia questions," questions to which the answers are known, people tend to underestimate their ignorance. The counterpart of this in business life might be the tendency to ignore unpleasant but unlikely outcomes. For example, those who lent almost a trillion dollars to developing countries seemed to ignore the likelihood of a massive default -- even though defaults had occurred during the 1930s and would be the predictable outcome of a tight-money recession.[4] Risk analysis could have shown the possibility of a severe downturn in oil and real estate and might have led bankers to be more prudent in the early 1980s.

In practice, careful risk analysis is rarely performed. Businesses routinely forecast the "most likely" outcome for sales, costs, profits, and so forth. The upside and downside risks are almost never examined in a systematic fashion. The purpose of this paper is to suggest a methodology for performing systematic risk analysis, to apply this methodology to higher education, and to assess both

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[3] See Arrow [1982], Tversky and Kahneman [1974], Kahneman, Slovic, and Tversky [1982]. and Kunreuther [1978].

[4] An excellent history of the history of folly in LDC lending is contained in Dornbusch [1989].

qualitatively and quantitatively the macroeconomic risks faced by colleges and universities.

More precisely, the paper will begin by specifying a highly simplified model of financial flows, a model that allows us to identify the major relevant economic uncertainties. After the financial flows are identified and the stochastic structure of the flows is examined, the risks faced by higher education can be assessed.

A. BACKGROUND ASSUMPTIONS

1. Risk Analysis

We begin with a short description of the methodology of risk analysis.[5] Denote a vector of endogenous variables to be determined by the model in period t by Y_t; a vector of exogenous variables determined outside the model and taken as random by X_t; and a vector of parameters that define the model by **k**. The model can be represented mathematically by:

$$Y_t = G[X_t;\mathbf{k}].$$

In the application that follows, a university's endowment income, tuition (we use the term "tuition" to include tuition, room, and board), and faculty salaries are among the endogenous variables of interest, while stock-market returns, interest rates, and inflation are among the critical exogenous variables. The parameters include such

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[5] This methodology has been applied to estimate probabilities of different trajectories for greenhouse warming in Nordhaus and Yohe [1983].

quantities as the share of wages in total expenses or the university's endowment at the beginning of the period.

Most forecasts present the expected value of the relevant variables, $E[Y_t]$, but do not systematically study the full distribution of the endogenous variables. In risk analysis, however, we will be concerned with not only the expected value or most likely outcome but also with some measure of the risk or dispersion of the variables of interest. In this study, we will limit our estimates to the mean and the standard deviation of the variables, respectively $E[Y_t]$ and $s[Y_t]$.[6]

If, in general, the probability distributions for the X_t variables and the k parameters were known and the $G[-;-]$ relationship were well established, then it would be straightforward to generate distributions of the components of the Y_t vector. In most cases, the $G[-,-]$ function is not well established, and the future values of the exogenous variables are unknown.

In what follows, we simplify the problem in two ways: First, the structure of the system -- the G function -- is represented by an extremely simply financial model of colleges and universities. While this stylized model is not designed to represent the finances of any particular institution, it is sufficiently simple and transparent that it can easily be modified to fit the finances of a given institution. Second, the probability distributions of the exogenous variables are determined from historical data. These exogenous variables are ones like GNP growth or real-wage growth that exhibit sufficiently stable behavior over

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[6] In some applications, use of certainty equivalence is appropriate. An analysis of the limitations of certainty equivalence is contained in Brainard [1967].

time that we can approximate their future uncertainty by looking at their historical behavior.

To summarize the methodology, we will create a simple model of the finances of a university, written as $Y_t = A X_t$ where A is a matrix of coefficients. We then estimate the distribution of X_t from historical data to obtain an estimate of the first two moments of Y_t, namely $E[Y_t]$ and $s[Y_t]$.

2. Model of a Large Research University

We begin with the example of a large research university. In the example, we have used the income and expenses of Yale University, although the data for Harvard and Stanford would not look dissimilar. Our model university is assumed to have a large undergraduate college, a medical school (but no hospital), and a handful of professional schools. Approximately half the income is drawn from tuition; one-fifth comes from gifts and endowment income; grants and contracts contribute one-fifth of income; the balance is from medical services and miscellaneous sources.

Table 1 contains the list of variables, definitions, and sources for the equations that follow. Variables are in upper case for dollar flows (e. g., Q represents real GNP), while lower case letters in brackets represent rates of change of variables (i. e., [q] is the rate of growth of real GNP or the rate of growth of Q). Variables are generally in real (inflation-corrected) terms except for the price level, the interest rate, and stock market prices.

Table 2 represents the income statement of our model research university. In our analysis, we will focus on total income, total expenses, and the income-expense ratio. The final goal is to determine the risk in the rate of growth of income and expense. Again, recalling that upper-case letters are flows while lower-case variables represent the rates of change of the variables, we define total income as I. From Table 2, total income is given by:

$$I = T + C + N + D.$$

Under the assumptions laid out in Tables 1 and 2, we can rewrite income as:

$$I = [B*S*P] + [\alpha_1 G*P + \alpha_2 Q*P] + [\alpha_3 M + \alpha_4 R + \alpha_5 Q*P] + [\alpha_6 G*P + \alpha_7 Q*P]$$

The coefficients, $\alpha_1,\ldots,\alpha_7$, are the coefficients that give the components of each item in total income. The four terms is brackets represent the major income items, which constitute 50, 20, 20, and 10 percent of income, respectively.

We are interested in determining the rate of growth of income, which is [i]. With a little manipulation, we can find the growth of income as the following:[7]

$$[i] = .5\ [p + b + s] + .2\ [.2\ q + .8\ g + p] + .2\ [.5\ m + .3\ r + .2\ (q + p)] + .1\ [.5\ g + .5\ q + p]$$

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[7] The results in the paper rely on the following mathematical results: Let X=I/E. Then taking the logarithmic derivative of X with respect to time yields dln(X)/dt = the rate of growth of X = [x] = dln(I)/dt - dln(E)/dt = [i] - [e]. Moreover, if I = X + Z, then [i] = a [x] + b [z], where a=X/I and b=Z/I.

We further simplify by assuming that the level of real activities are constant over time; that is, the size of student body and faculty are constant. This assumption is justified because enrollment is generally not demand-constrained but instead by non-economic considerations.[8]

Collecting terms, we have:

(1) [i] = .5 [b] + .13 [q] + .21 [g] + .1 [m] + .06 [r] + .84 [p]

Equation (1) shows how changes in exogenous economic variables affect our model university. As an example, this equation shows that if GNP growth, [q], increases by 1 percent, then the income of the model university increases by .13 percent. Clearly income is quite sensitive to inflation and tuition, but the coefficient on government spending, [g], is also of considerable importance.

Turning next to expenses, the expenses of our model university are shown in Table 3 with the variables and relationships contained in Table 1. Slightly more than half of expenses are labor costs -- faculty and staff -- while scholarship aid is one-tenth of expenses. The balance is materials and supplies, which are assumed to be a representative slice of GNP.

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[8] For those institutions whose enrollments are subject to significant fluctuations (because of student choice, not institutional choice), the model would need to be altered. Moreover, public institutions are primarily dependent on state spending and, consequently, the health of their state economy; models of publicly supported institutions must obviously reflect these realities. It should be noted, however, that from a technical economic point of view, the adjustment of activity levels by the institution has no net first-order effect on the objective function (by the envelop theorem), so the assumption of no change in activity levels is inessential to the results that follow.

Defining E to be total expenses, we calculate total expenses as follows:

$$E = F + L + A + O$$

or

$$E = \beta_1 * W * (1+[f]) * P + \beta_2 * W * P + \beta_3 * T + \beta_4 * P * Q$$

where $\beta_1, \ldots, \beta_4$ are coefficients. In the example analyzed here, the shares of the terms in the expense equation are 25, 30, 10, and 35 percent, respectively. Manipulating expenses, we obtain the rate of growth of expenses, [e], as the following:

$$[e] = .25 \; [w + f + p] + .30 \; [w + p] + .1 \; [p + b + s] + .35 \; [p + q]$$

or

$$(2) \quad [e] = .55 \; [w] + .25 \; [f] + .1 \; [b] + 1.0 \; [p]$$

It is important to note that wages have a high weight in universities because of the labor-intensive nature of educational production.

Finally, we want to calculate a measure of the overall financial posture of our university. The conventional measure is the institution's surplus or deficit. Such a measure is unsatisfactory because actions are generally taken to produce a balanced budget. A more appropriate measure is the _ex ante_ surplus or deficit, which measures the state of the budget, or the impact of exogenous variables like the stock market or inflation upon the budget, before any counteracting policy steps are taken by the university. For convenience, we will examine a normalized measure of the _ex ante_ budget that we will call the "income-expense ratio," X, which is defined as Income/Expense, or X=I/E. Use of the income-expense ratio abstracts from the institution's size. Generally, universities target this to be 1. When X is less than 1, the system is in deficit, while a ratio of X greater than 1 signifies a surplus. From (1) and (2), we have the growth rate of the income-expense ratio, defined as [x], as:

$$(3)\quad [x] = .1\,[m] + .13\,[q] + .4\,[b] + .06\,[r] + .21\,[g] - .55\,[w] - .25\,[f] - .16\,[p]$$

When the budget is balance over time, X = 1. As a result, [x] is equal to zero, and income and expenses are growing at the same rate. When [x] is negative, the system is moving into deficit, while if [x] is positive the system is moving into surplus.

Looking at equation (3), we can see the vulnerability of colleges and universities to different forces. Five forces work in a favorable direction: the stock market through its impact on the value of endowment; the economy through its impact upon giving and contracts; the escalation of tuition and other fees above the rate of inflation; higher real returns on the fixed-income portfolio; and higher discretionary government spending.

The identified negative forces are three: increases in wages over the general price level; escalation in faculty salaries; and higher inflation.

The coefficients in equation (3) give a rough idea of the impact of variation in different forces upon the finances of higher education. They indicate, not surprisingly, that universities are quantitatively most sensitive to tuition changes, along with movements in real wages and in faculty salaries. In addition, the government budget enters in a significant way, as do financial returns and inflation.

2. A Small Private College

The above analysis can be easily modified to apply to other kinds of institutions. We present here another example, that of a small private college. Tables 4 and 5 show the income and expense statements of a model small private college. The major differences between the college and the research university are: the absence of a medical school and the lack of medical service income; a much smaller volume of grant and contract income; a larger fraction of the budget devoted to faculty and staff; and higher income coming from tuition and fees.

Again we represent income by I, and the rate of growth of income [i] is given by:

$$
\begin{aligned}
[i] = {} & .65\,[p + b + s] + .05\,[.2\,q + .8\,g + p] \\
& + .2\,[.5\,m + .3\,r + .2\,(q + p)] \\
& + .1\,[g + p]
\end{aligned}
$$

We hold the size of the student body and faculty constant. Collecting terms, we have:

$$(4) \quad [i] = .65\ [b] + .05\ [q] + .14\ [g] + .1\ [m] + .06\ [r] + .84\ [p]$$

The expenses of our model small college are given in Table 5. Slightly more than half of expenses are labor costs -- faculty and staff -- while scholarship aid is two-tenths of expenses. The balance is materials and supplies.

Again defining E to be total expenses, we calculate the rate of growth of expenses [e] to be the following:

$$[e] = .35\ [w + f + p] + .25\ [w + p] + .2\ [p + b] + .20\ [p + q]$$

or

$$(5) \quad [e] = .60\ [w] + .35\ [f] + .2\ [p + b] + .8\ [p]$$

Again we assume that the income-expense ratio (X = I/E) is near 1. From (4) and (5), the growth rate of the income-expense ratio, defined as [x], is:

$$(6) \quad [x] = .1\ [m] + .05\ [q] + .45\ [b] + .06\ [r] + .14\ [g] - .60\ [w] - .35\ [f] - .16\ [p]$$

A comparison of equations (3) and (6) shows the different vulnerabilities the small college and the large research university. The large university is slightly more vulnerable to shocks to the overall economy and to government spending.

The college is more heavily affected by variables that are idiosyncratic to higher education, such as the escalation factors in faculty salaries and in tuition. But the major influences are surprisingly similar for the large university and the small college.

However, we cannot judge the risk of the different forces until we estimate the variability of each variable. In other words, the quantitative risk due to each factor is the product of the vulnerability coefficient in (3) or (6) times the risk of the individual variable. We turn next to an estimate of the risk of each variable.

B. Riskiness of Each Factor

In analyzing the riskiness or variability of each factor in equations (3) and (6), we focus on the medium-run exposure for a university, taken to be a period of three years. To calculate the risk, we examine two sorts of data: (1) First we examine the DRI forecast for the economy. Calculating the variability of the different variables across different DRI scenarios, we can gauge the relative variability of those variables included in the DRI system. (2) A second technique examines the relative variability of the different variables over the post-war period. This second approach simply asks how much the relevant variable has moved in recent years.

1. DRI Forecasts

Each month, DRI provides not only a standard or baseline forecast but also a set of alternative forecasts. To measure potential risks to the key variables, we examined the different forecasts and weighted them by their probabilities. For example, in October 1988, DRI had four different forecasts: a baseline, a tight-money, an easy-money, and a fiscal-solution forecast. These were assigned probabilities of 50, 25, 20, and 5 percent, respectively.

To estimate the uncertainty, the forecasts of the relevant variables were taken from the four forecasts, and an estimate of the forecast standard deviation was made for each variable. All variables were included except stock prices, for which no data were provided.

The standard deviations of the forecasts are shown in column (2) of Table 6.

2. <u>Historical forecasts</u>

A second approach is to examine the historical forecast errors or volatility of the different factors. If the underlying uncertainties are relatively stable over time, the historical uncertainties will be reasonably good predictors of future uncertainty.

The technique for estimating the historical uncertainty is demoted to a footnote, but the essence is easily described. For each variable, a time series is constructed using the data definitions shown in Table 1. Then a time series of three-year changes in the rate of growth of each variable is constructed; three years is chosen as a realistic length for the full budget cycle in a college or university. Finally, estimates of the standard deviation of the rate of growth are calculated along with several estimates of the forecast errors generated by simple single-equation forecasts.[9] These estimates appear in column (3) of Table 6. In addition, the historical estimates have been broken into two subperiods in Table 7.

3. Discussion of Uncertainties

Two major conclusions follow from the results in Tables 6 and 7. First, the historical data show a significant change in the underlying volatility of some variables. For example, interest rates appear to be twice as variable in the second half of the period as in the first half. This finding conforms to changes in the conduct of monetary policy, which became much more active and willing to induce major changes in interest rates, particularly during the 1979-1982 period. In addition, inflation and the price level became more unstable in the 1970s and 1980s, which was the period of the oil shocks and major changes in the dollar exchange rate. Government spending on goods and services became less

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[9] For concreteness, we illustrate the technique for estimating the uncertainties using GNP as an example. We begin with a time series on real GNP, Q, running from 1947:I to 1987:IV. We then construct a series, D12LQ, which is the twelve-quarter difference in the logarithm of real GNP. That is,

$$D12LQ = \log(Q_t) - \log(Q_{t-12}),$$

where t is measured in quarters. We then calculate the standard deviation of D12LQ over the sample period 1954:I to 1987:IV, which is the entry in column (2) of Table 7. The entries in columns (3) and (4) show the estimated standard deviations of the variables for different subperiods. Finally, we have estimated equations that predict changes in each of the variables on the basis of information available three years' earlier. For these regressions, we have used all the factors shown in Table 7, and the estimates of the risk are shown in the last column of Table 7. It should be noted that, because they are in-sample standard errors, the estimates in column (5) are likely to underestimate the actual forecast errors.

volatile in the second half of the period. Other variables show relatively little change in variability. Stock prices were marginally more volatile--largely because of 1987, however. Output and real wages showed no major change in volatility over the period.

The other major conclusion comes from comparing the DRI forecast risks and the historical variability. A comparison of columns (2) and (3) in Table 6 shows that the DRI risks have no systematic connection to the historical volatility. Every variable displayed has lower risk than would be justified on historical grounds. Moreover, although the difference is modest in the case of interest rates and real GNP -- where the understatement is one-half to one-third -- it is enormous for the price level and government spending, where the understatement is by factors of 20 to 25.

Given the difference between the DRI forecast risks and the historical data, we should probably interpret the DRI alternative forecasts as "scenarios," that is, as plausible paths that might be followed under conditions of tight money or fiscal compromise. However, it would be perilous to rely upon these scenarios as a complete or even approximate description of the risks faced in the macroeconomy.

Given the likelihood that the DRI estimates of risk are not based on a systematic risk analysis, we will rely instead upon the risk estimates from the historical data. But the failure of the DRI risks to approximate historical risks underlines the contention at the beginning of this paper that economic agents, even highly sophisticated and successful forecasters like DRI, not only underestimate the degree of uncertainty but also do not appear to pay systematic attention to the inherent risks in their business.

4. Further Analysis of Scenarios

a. Informational requirements of risk assessment

Before applying the results to colleges and universities, we pause to consider the problems involved in analyzing and presenting the risks in large systems, particularly in macroeconomic models. The issues we address are: (1) what are the informational requirements of a risk analysis and (2) how well can scenarios transmit the information required for a risk analysis.

In analyzing this issue, we begin with a model of a large complex system. Using the earlier notation, we examine a linear, interdependent system with a vector **Y** of N endogenous variables; and a vector **X** of M exogenous variables determined outside the model and N random disturbances. For this example we abstract from the problem of dynamics and consider only a one-period forecast.[10]

The model can be represented mathematically by:

$$\mathbf{Y} = \mathbf{A}\mathbf{X} \qquad (7)$$

where **A** is a N x (M+N) matrix of coefficients.

For our purpose, we define a "risk analysis" as a set of parameters or estimates that allow an analyst to calculate the standard deviation of **Y** or any linear combination of **Y**. In the example of this study, the purpose is to calculate the standard deviation of the growth of the income-expense ratio,

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[10] If we were to consider a dynamic model, forecasting T periods rather than 1 period, the size of the problem would be increased by a factor of T.

[i], given in (3) and (6). At first blush, it would seem straightforward to present the results of a risk analysis by simply giving the variances of **Y**. In complex systems, however, the variables are correlated and a major mistake could be made by assuming them statistically independent. For example, in judging the quality of its loan portfolio, a bank might in 1978 simply have looked at interest rate risk and GNP risk. This risk assessment would have erred by overlooking the risk of a tight-money recession, with the high real interest rates and deep recession that were experienced in the early 1980s. Therefore part of a full risk assessment is presentation of the covariances as well as the variances.

To examine the full informational requirements of a risk assessment, we assume that the system is stationary; that is, the underlying parameters and error processes do not change over time. Given stationarity, it is useful to represent the system through its Wold decomposition as follows. Let Z be a vector of K unit variance, mutually independent, serially uncorrelated variables (which may include simple transformations of the **X** variables). Then under certain circumstances we can represent **X** as:[11]

(8) $$\mathbf{X} = \beta Z \quad .$$

Combining (7) and (8), we get:

(9) $$\mathbf{Y} = \mathbf{A}\beta X = \Gamma Z,$$

[11] A sufficient set of assumptions is that the **X** are stationary, indeterministic stochastic processes. For an analysis of the statistical theory, see Sims [1972].

where $\Gamma = A\beta$. Equation (9) is convenient because any risk analysis can take into account that the exogenous Z variables are independent, so that the variance-covariance matrix of Z is the identity matrix. In general, the dimensionality of Γ (K) will be at least as large as the number of random disturbances (N) and for most macroeconomic models will generally be very large. For example, assume that there are 50 important endogenous macroeconomic variables, 50 random disturbances, and 150 important independent exogenous variables, and that each exogenous variable and disturbance has four lags. Then Γ will have dimensions of 800 x 50. Given that Γ involves a transformation of variables, it is difficult to know the number of non-zero elements in Γ, but it seems likely that there will be at least 1000 and the upper bound is 40,000.

We can now understand the informational difficulties in a full risk analysis of a large system. The amount of information that must be transmitted for a point forecast (a forecast of expected values) is relatively modest and involves only N pieces of data for the macroeconomic model described here. A risk analysis of the entire system, however, requires transmitting the variance-covariance matrix for all endogenous variables, **Y** (or perhaps for both endogenous and exogenous variables, **Y** and **X**). This involves transmitting all the non-zero elements of the Γ matrix in (9), along with the non-trivial job of describing the complicated variables constructed in the Wold decomposition in (8). Thus the number of data points for the point forecast is in the order of N while the number of data points for the risk analysis is somewhere between N and NxK, where K is larger than N. In complex and highly connected systems, then, the informational requirements needed for risk assessment is enormous.

b. Scenarios and risk assessment

The analysis of the last section can be used to describe the hazards of use of scenarios in risk assessment. There are three perils that analysts encounter in substituting scenarios for full risk assessments: neglect of probabilities, attention to a limited number of risks, and an intrinsic lack of sufficient information.

The most common problem in scenario construction is the failure to pay careful attention to estimation of probabilities in constructing scenarios. In most scenarios, the "high" and "low" are simply chosen by the analyst without regard to historical experience or even, in most cases, without defining the likelihood of the scenario occurring.

A second difficulty arises because of attention to but a limited number of possible risks. In the DRI scenarios, for example, only monetary and fiscal policy changes were examined. Many of the other risks of macroeconomic life (exchange-rate movements, stock-market crashes, oil-price movements, droughts, etc.) were ignored. The differential attention accorded to different variables has two predictable effects upon the risk analysis. First, because only a fraction of the risks are examined, the overall risk to the endogenous variables is understated. In the DRI estimates in Table 6, note that all risks are understated relative to historical risks. A second predictable outcome is that those variables that are highlighted in the scenario construction have relatively high estimated risk while those which are ignored have relatively low risk. Hence, in the DRI scenarios, the risks to interest rates and GNP are understated by only a factor of two or three because the scenarios train their attention on interest-rate and output risks; other variables, such as inflation or government spending, were not addressed in the scenario construction, and these variables' risks are understated by a factor of 20 or 25.

A third point concerns the inherent defect of scenario construction in terms of the insufficiency of the data transmitted by scenarios. Each scenario contains at most M pieces of data; these being the forecasts of the endogenous and the exogenous variables (N+M estimates) less the number of constraints from the N equations. (In fact, the typical scenario contains much less information, for only 3 or 4 variables are changed in the typical DRI scenario.) Yet to transmit the information for a complete risk analysis, the modeler needs to convey the non-zero (or non-trivial) elements in the Γ matrix.

To use the figures in the last section, we estimate that the number of non-zero elements in the Γ matrix of a medium-sized macroeconomic model will be between 1000 and 40,000. The number of pieces of information transmitted in the typical DRI simulation is in the order of 4. The maximum that can be transmitted in a scenario is 200 pieces of information. Therefore, to transmit the full information requires 250 to 10,000 DRI style scenarios, or from 5 to 200 maximally efficient scenarios. These bare informational requirements ignore the difficulties of attempting to extract the information from the scenarios and using the information in run-of-the-mill activities.

In summary, this example shows that transmitting information about risk is much more difficult than for point forecasts. It also suggests that scenarios are a poor tool for transmitting the risk data in complex, highly interconnected systems.

C. <u>ESTIMATES OF RISKS FOR HIGHER EDUCATION</u>

We can now use the estimates of risk to obtain estimates of the impact of different external economic events upon higher education. The basic technique is the following: We first analyze the weights of the most important factors affecting the finances of higher education; we then estimate the inherent risk attached to each factor; finally, we fold together the weights of the factors with the risks of each factor to obtain the impact of economic uncertainties on higher education.[12]

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[12] More precisely, the technique is the following. Let the finances be described by a linear function

(i) $$y = a_1x_1 + a_2x_2 + \cdots + a_nx_n ,$$

where a_i = weight attached to factor i. We then calculate the risk to the overall finances as a function of the individual risks. Defining s(y) as a measure of the risk to the overall finances (more precisely, as the standard deviation of y), we calculate

(ii) $$s(y)^2 = s[(a_1x_1 + a_2x_2 + \cdots + a_nx_n)^2].$$

If the x_i's are statistically independent, then s(y) is given by:

(iii) $$s(y)^2 = a_1^2\ s(x_1)^2 + a_2^2\ s(x_2)^2 + \cdots + a_n^2\ s(x_n)^2.$$

Two estimates of the impact of the risk are shown in Table 8 in the lines under TOTAL. The first line, labelled "actual" represents the actual risk according to equation (ii). The second line, labelled "independent," calculates the risk according to the formula in (iii), which assumes the variables are statistically independent.

1. Overall Risks

Table 8 shows the estimates of the weight or importance of the different factors. Column (2) shows the weights for our model research university derived from equation (3), while column (3) shows the weights for our model small college derived from equation (6).

The last two columns in Table 8 show the calculated impact of risk for both universities and colleges. The last two rows in Table 8 show the total risk, with the estimate labelled "actual" representing the risk of the calculated formulae in (3) and (6) and the "independent" estimate showing what the risk would be if there were no correlations among the factors listed in the table.

The interpretation of the "impact" is the following: For each factor, and for the total, we have taken the intrinsic volatility or risk of the variable (shown in column (4) of Table 6) and multiplied the risk times the weight shown in Table 8. The product of the weights and risk is the total impact. For example, the stock market is estimated to have an inherent volatility of 21.1 percent per three-year period; the stock market is found to have a weight of 10 percent in the budgets of our model institutions; therefore the overall impact of the stock market is a risk factor of 2.11.

The interpretation of the units of the impact is the following: Recall that we are using as an index of the financial position of educational institutions the logarithm of the income-expense ratio. The impact measure shown in Table 8 is the standard deviation of the logarithm of the income-expense ratio, measured in percent. Therefore, the risk is a proportional measure of risk relative to the entire budget of the institution.

More precisely, the second from the bottom entry in the second from the last column in Table 8 states that the risk for universities is 4.14. This signifies that the estimated standard deviation of the income-expense ratio is 4.14 percent. Because of the normalization, this means that the "risk" is calculated to be 4.14 percent of the budget (i. e., either income or expense, which are assumed equal) of the institution. For example, if the university has a budget (both income and expenses) of $100, then the standard deviation of the budget, before any policy adjustments are taken by the institution, is calculated to be 4.14 percent of the budget = $4.14 million.[13]

To explore the interpretation further, we show in Figure 1 the movement over time in log(X), the logarithm of the income-expense ratio for both colleges and universities. Examine the estimated curve for research universities, shown as the solid line in Figure 1. During the period from 1954 until the mid-1960s, the external factors were extremely favorable, as is shown by the rapid growth of the income-expenses ratio. From the mid-1960s until the early 1980s, the trend was basically neutral, with sharp drops in the late 1960s, the early 1970s, and during the early 1980s. In the last three years examined, 1985-87, the external factors were

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[13] It is important to distinguish between the movements in the ex ante and the ex post budgets. The following example will clarify the difference. Say that in year 1 our university has a one-standard-deviation unfavorable ex ante shock to its $100 million budget. If the university took no offsetting policy measures, it would experience a deficit of $4.14 million. Usually, operating guidelines require a budget adjustment. The university might, for example, cut expenses and raise fees so as to trim the deficit to $1 million. In this case the policy adjustment is $3.14 million in the direction of surplus and the ex post deficit is $1 million. If the budget is completely successful in offsetting shocks, then the ex post budget would always be balanced.

relatively unfavorable due to trends in government spending and a decline in stock prices.

The long-term trend for colleges is less favorable over the period although the short-term trends look quite similar to those for universities. The major difference between small colleges and research universities lies in the contribution of government, particularly support for the life sciences, which has contributed significantly to the financial growth of research universities through rapid growth of support for biomedical research.

Figure 2 shows the forecast errors, or historical risks, faced by our two institutions. This graph measures the annual rate of growth of the income-expense ratio. When the rate of growth is positive, this signifies that there is a favorable shock to the income-expense ratio, while a negative number, representing a negative rate of growth in that variable, is an unfavorable development for colleges and universities. A word on the units is important: When the line in Figure 2 reads .05, this signifies that the budget is 5 percent in surplus over what a straight extrapolation would provide. When the figure is -.02, this means that the budget is in deficit by about 2 percent of income or expenses. Figure 2 shows the same trends as Figure 1, namely that events were generally favorable from the mid-1950s to the late 1960s and generally unfavorable from the late 1960s to the mid-1980s.

Another way of examining the risk is to look at the distribution of forecast errors in [x]. Table 9 shows the frequency of shocks of different sizes for the historical period, 1954-87, for both research universities and small colleges. This table shows that research universities experienced unfavorable shocks of more than 5 percent of the budget in 2 of 34 years, and unfavorable shocks of between 3 and 5 percent of the budget in 4 of 34 years. Small colleges were less severely hit, experiencing unfavorable shocks of more than 3 percent only 2 of 34 years.

Table 10 tabulates the relative frequency of the historical shocks along with the theoretical distribution derived in Table 8. The theoretical distribution is derived by assuming that the distribution of shocks is normal with a standard deviation estimated in Table 8; the theoretical distribution shows somewhat greater exposure in the tails than does the historical experience. The bottom of Table 10 shows the estimated and actual frequency of large and severe unfavorable shocks.[14] The theoretical risk analysis suggests that severe shocks of more than 5 percent of the budget should occur 12 percent of the time for research universities and 5 percent of the time for small colleges; this theoretical calculation matches the experience of research universities but overestimates the historical risk for small colleges. The frequency of large unfavorable shocks of more than 3 percent of the budget is predicted by the risk analysis to be 24 percent and 15 percent for universities and colleges, respectively; the actual distribution is 18 and 6 percent, respectively.

How "large" are the shocks that are analyzed here? A rough guess is that a shock to the income-expense budget of 3 percent or more will be quite painful. For example, in a college or university with a budget of $100 million, this shock would require income increases or budget cuts of around $3 million to balance the budget. As an example, for a small

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[14] For purposes of exposition, we call a shock of more than 3 percent of the budget (or, equivalently, of the income-expense ratio) a "large" shock and a shock of more than 5 percent of the budget a "severe" shock.

college, a shock of 3 percent would require raising tuition about 4 percent more than trend or would require a cut in staffing of approximately 6 percent. Judging from experience at Yale and similar institutions, staffing cuts of 5 to 10 percent are extremely painful for the institution, while increases in tuition of 3 to 5 percent above trend raise a loud howl from alumni, students, and their families.

How often will such large shocks occur due to the risk from external events? Looking at the historical data, the risk estimates suggest that shocks of 3 percent or more will occur approximately one year out of five for large research universities and for one year out of sixteen for small colleges. The painful reactions discussed in the last paragraph will then be required unless provision is made for the inherent risks.

2. Risks from Different Sources

The analysis here is designed not only to estimate the inherent financial risks to higher education, but also to examine the risk that comes from individual factors.

The first six rows of Table 8 showed the risks associated with different factors. In addition, we have shown these results graphically in Figure 3 (for our model research university) and in Figure 4 (for our model small college). A word of interpretation of Figures 3 and 4 is in order. Each figure shows three bars for each factor and for the total. Starting from the left, the bars in the chart for each factor represent: (a) the weight of each factor, its relative importance in the budget; (b) the volatility of each factor, the extent to which a particular factor is unpredictable; and (c) the overall impact of volatility of each factor on college and university budgets. The scale on the vertical axis is the standard deviation (in percent) for both the volatility and the impact and 0.1 the percentage weight.

A number of results stand out from the figures and tables:

a. The major surprise that appears in Table 8 is the very great volatility that comes from the government budget. This conclusion will not be surprising for public universities, who are used to legislative risk, but it may come as a major surprise to private universities. The reason for the great inherent risk from the Federal government is not only that a large part of the budgets of higher education is derived from the Federal government, but also that this has been a highly volatile spending stream. It may well be that the period ahead, as the Federal government confronts its large deficit in a serious way, is a period of particular risk to higher education.[15]

b. The risks from financial markets are well known to colleges and universities. These risks come from the inherent volatility of stock and bond markets. Many universities tend to "smooth" the financial uncertainties by calculating the income from endowment according to a weighted

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[15] Measuring the risk from the government budget is particularly difficult for three reasons. First, the education share of the federal budget is relatively small, so special forces may changes trends very quickly. Second, the behavior of the federal budget appears to have changed sharply over the last four decades, with much less volatility in recent years. Third, and most important, is that measuring the component of the federal budget is particularly difficult because so much of the contribution is indirect (loan guarantees, indirect cost recovery, indirect support of faculty salaries, and funding of biomedical research and hospitals) while virtually none of the support is direct.

average of past market values. This smoothing will make the year-to-year adjustments to financial-market volatility less painful, but they will not remove the long-run need to adjust.

c. The impact of wages and the price level (or inflation) is intermediate in impact upon colleges and universities. Wages have the potential of being extremely important risks, because they constitute such a large share of expenses, but fortunately they are relatively stable and predictable and therefore pose only minor financial risk. Inflation has often been held to be the bugaboo of higher education, but its impact may have been overestimated. For the most part, both income and expenses of colleges and universities move with inflation, so that there is little "real" impact of inflation on higher education. The major impact can be seen from the loss of buying power if the endowment erodes in inflationary periods.

d. Finally, it is surprising how little direct impact the business cycle, through real GNP growth, has upon colleges and universities. On reflection, this is not surprising for two reasons. First, GNP turns out to be relatively predictable over the medium run (even though it may have large elements of unpredictability in the short run). Second, colleges and universities are remarkably insulated from the business cycle. Most top-rated universities are not demand-constrained; unlike automobile manufacturers or department stores, the level of "output" of colleges and universities is determined by internal, non-pecuniary considerations and is unaffected by small changes in the real incomes of households or the exchange rate on the dollar.

e. It should be recalled that the risks analyzed here pertain only to those variables that are external to higher education. That is, we have ignored the impact of industry variables such as changes in tuition and the escalation of faculty salaries. These are omitted for two reasons: First, they are at least in part under the control of higher education, and therefore cannot be taken as exogenous to university decisions. That is, they are, at least in part, decision variables rather than external factors in university finances. In addition,
tuition and the escalation of faculty salaries adjust to the finances of higher education. If the finances of higher education are strained, this will tend to raise tuition and lower faculty salaries. So there is an element of self-adjustment in tuition and faculty salary escalation.

3. <u>Conclusions</u>

We now summarize the results and draw some final conclusions. This study analyzes systematically some of the major economic risks facing institutions of higher learning. We began by constructing budgets of a stylized small college and research university, and we analyzed the major economic factors affecting those budgets. The major external factors analyzed were real GNP, the stock market, interest rates, Federal government spending, inflation, and real wages.

Next, we analyzed both the historical volatility (or unpredictability) associated with each major external variables, along with the compound uncertainty associated with the total externally determined factors. Based on historical data, we estimated that universities would be subject to major unfavorable shocks (greater than 3 percent of the budget) one year in five for major research universities and one year in 16 for small colleges.

In examining the major uncertain factors, the largest surprise was the importance of uncertainty about the Federal budget to colleges and universities. This concern is most important for research universities (particularly those with large programs and biomedical programs). The overall impact of potential volatility of government spending overshadows all other external influences. The next largest potential factor is the stock market, followed by interest rates, inflation, and wage trends. For small colleges, the uncertainty associated with government is also the most important single factor, although the stock market and other variables are close behind.

The exercise undertaken here has a number of important implications for the management of educational institutions. The first implication concerns the value of forecasting. Once the important risks have been identified, colleges and universities can track them carefully so as to get early warning of future trouble. It is clearly important for institutions to track Federal budget trends along with other major economic variables.

The most important application of this analysis, however, is to assist institutions in preparing for foul economic weather. The appropriate reaction of institutions to their risks is a problem that takes us far afield from the current topic, although the type of reaction is clearly intimately related to the risks that institutions run. In one sense, the risks are analogous to the risks of bad weather in the agricultural sector. There are two kinds response to bad harvests: anticipate them by building a grain stockpile or adjust to them afterwards by cutting food consumption. Similarly, colleges and universities can anticipate future financial shocks in advance by accumulating surpluses and retaining budgetary flexibility; or they can adjust to unfavorable shocks by having periodic financial crises and budget cuts after unfavorable shocks occur. Prudence would certainly lead to anticipating shocks by building in flexibility or storing financial reserves much as we store grain for years of drought.

At present, many institutions explicitly allow for risk in their spending from endowment. Rather than spending exactly the interest and dividends, or the estimated total return, many institutions have adapted to financial risks by smoothing the spending from endowment returns. Yale University is typical in this respect: it in essence uses exponential smoothing of spending with a current-year weight of 30 percent.

Surprisingly, institutions in general do not carry over the logic of their endowment spending to the entire budget. As this analysis has shown, endowment risk is typically but a fraction of the entire exogenous risk faced by a college or university. Yet, the institution is generally required to adjust immediately to shocks in oil prices or government spending, while it is accorded a significant grace period for financial shocks. It would seem useful to develop more general "spending rules" that allow an institution to buffer itself from exogenous risks and avoid the boom and bust cycle that has plagued academic life in recent decades. A "general spending rule" (as opposed to an "endowment spending rule") would prevent university's from undertaking hiring binges in financially prosperous years while spreading out the painful adjustment to periods of financial stress. Risk analyses of the kind presented here could be employed to develop institutional spending rules that would be the university's granary for the inevitable lean years.

Table 1

List of Variables Used in Tables and Text

Symbol	Variable	Definition and Source
A	Scholarship Aid	A = const * S * B * P = const * T
[a]	Rate of change of A	[a] = [A-A(-1)]/A(-1)
B	Inflation-corrected term bill	Average term bill in current prices divided by the GNP deflator
[b]	Term bill escalation rate	[b] = [B-B(-1)]/B(-1)
C	Grant and contract income	C = 20 percent derived from government spending (G*P) and 80 percent derived from overall economy (P*Q)
[c]	Growth of grant and contract income	[c] = .8 ([g] + [p]) +.2 ([q] + [p])
D	Medical service income	Derived from services of physicians in medical school, assumed 50 percent dependent on government and 50 percent dependent on overall economy.
[d]	Growth rate of medical service income	[d] = .5 ([g] + [p]) +.5 ([q] + [p])
E	Expenses of college or university	As defined in Tables 3 or 5
[e]	Rate of growth of expenses	[e] = [E-E(-1)]/E(-1)
F	Faculty Salaries	F = const * W * P * (1 + [f])
[f]	Faculty salary escalation, equal to the rate of growth of average faculty salaries minus the rate of growth of average wage rate.	

G	Real discretionary government spending	Federal spending on non-defense goods and services, 1982 prices
[g]	Rate of growth of discretionary government spending	[g] = [G-G(-1)]/G(-1), annual rate
I	Income of college or university	As defined in Table 2 or 4
[i]	Rate of growth of income	[i] = [I-I(-1)]/I(-1)
L	Staff compensation	Assumes staff compensation grows with average wages in economy (W * P)
[l]	Rate of growth of staff compensation	[l] = [w] + [p]
M	Stock prices	Stock price index for New York Stock Exchange
[m]	Rate of growth of stock prices	[m] = [M-M(-1)]/M(-1), annual rate
N	Endowment and gift income	N = 50 percent derived from stock-market return, 30 percent from bond returns, and 20 percent dependent on overall economic activity.
[n]	Growth of endowment and gift income	[n] = .5 * [m] + .3 * [r] + .2 ([q] + [p])
O	Other materials and supplies	Assume that prices of materials and supplies growth with overall GNP (P * Q)
[o]	Growth rate of prices of materials and supplies	[o] = [p] + [q]
P	Overall price level	GNP deflator
[p]	Rate of inflation	[p] = [P-P(-1)]/P(-1), annual rate
R	Long-term interest rate	Moody's Aaa interest rate, percent

[r]	Rate of change of interest rate	[r] = [R-R(-1)]/R(-1)
Q	National output	Real GNP, 1982 prices
[q]	Rate of growth of real GNP	[q] = [Q-Q(-1)]/Q(-1), annual rate
S	Size of student body	Student body assumed constant
[s]	Rate of growth of size of student body	[s] = 0
T	Total term bill	T = B * S * P
[t]	Growth rate of term bill	[t] = [b] + [s] + [p]
V	Government scholarship support received by colleges and universities	Assumed to grow with government discretionary income (G * P)
[v]	Rate of growth of government scholarship support	[v] = [g} + [p]
W	Real wage rate	Compensation per person-hour, business economy, divided by GNP deflator.
[w]	Rate of growth of wages	[w] = [W-W(-1)]/W(-1)
X	Income-expense ratio	X = I/E
[x]	Growth of income-expense ratio	[x] = [i] - [e]

Table 2. **Income Statement of Model Research University**

Income Item	Symbol	Share	Determinants
Term Bill	T	50%	Number of Students (S) Term Bill (PB)
Grants and Contracts	C	20	Government Discretionary Spending (PG) GNP (PQ)
Gifts and Endowment Income	N	20	Stock Market (M) Interest Rate on Bonds (R) GNP (PQ)
Medical Income	D	10	Government Discretionary Spending (PG) GNP (PQ)

Table 3. **Expense Statement of Model Research University**

Income Item	Symbol	Share	Determinants
Faculty	F	25%	Nominal wages (WP) Faculty salary escalation (f)
Staff	L	30	Nominal wages (WP)
Scholarship Aid	A	10	Fraction of Tuition Income
Other materials and supplies	O	35	GNP (PQ)

Table 4. **Income Statement of Model Small College**

Income Item	Symbol	Share	Determinants
Term Bill	T	65%	Number of Students (S) Term Bill (PB)
Grants and Contracts	C	5	Government Discretionary Spending (PG) GNP (PQ)
Gifts and Endowment Income	N	20	Stock Market (M) Interest Rate on Bonds (R) GNP (PQ)
Government Scholarship Assistance	V	10	Government Discretionary Spending (PG)

Table 5. **Expense Statement of Model Small College**

Income Item	Symbol	Share	Determinants
Faculty	F	35%	Real wage growth (WP) Faculty salary escalation (f)
Staff	L	25	Real wage growth (WP)
Scholarship Aid	A	20	Fraction of Tuition Income
Other materials and supplies	O	20	GNP (PQ)

Table 6. **Risks in Different External Factors**
[Percent forecast error or uncertainty,
three-year horizon]

(1) Factor	Factor Risk (2) DRI	(3) Historical	(4) Assumed
Stock Market Prices	--	21.1	21.1
Interest Rate	9.4	18.9	18.9
Government	0.67	16.3	16.3
Real GNP	1.4	4.3	4.3
Real Wages	0.69	2.1	2.1
Price Level	0.39	7.0	7.0

Note on units: The Factor Risk in columns (2) through (4) represent the volatility of the underlying factor, measured as the uncertainty of the factor over a three-year period. For example, a forecast of the stock market is assumed to have an uncertainty of 21 percent over a forecast horizon of three years. Definitions of the variables are provided in Table 1.

The estimates for the DRI model are taken from Data Resources [1988].

Table 7. **Uncertainties Associated with Different External Factors**

[Percent forecast error or uncertainty,
three-year horizon]

(1)	(2)	(3)	(4)	(5)
	Factor Risk			
Factor	Total Sample	1954-69	1970-87	Forecast
Stock Market Prices	21.10	17.64	22.34	19.10
Interest Rate	18.99	12.51	23.03	16.87
Government	16.30	20.16	11.51	13.14
Real GNP	4.31	3.83	4.44	3.43
Real Wages	2.14	1.14	1.09	1.30
Price Level	7.01	2.49	5.45	3.91

Note: The uncertainties in columns (2) through (4) are standard deviations of 3-year differences in the variables. For example, the first row represents the standard deviation of $[m_t] = \log(M_t) - \log(M_{t-3})$, where M_t is the stock-price index for year t. The forecasts in column (5) represent the standard error of a regression that uses prior information about the factor in column (1); in general, the prior information was all the listed variables lagged three years.

Table 8. **Weights and Total Impact of Different Risky Factors**

(1)	(2)	(3)	(4)	(5)
	WEIGHT OF FACTOR [Percent of total income or expenses]		TOTAL IMPACT [Equal to weight of factor times factor risk. Unit is standard deviations of log of income-expense ratio. Measured as percent of total budget.]	
Factor	University	College	University	College
Stock Market	10.	10.	2.11	2.11
Interest Rates	6.	6.	1.13	1.13
Government	21.	14.	3.42	2.28
Real GNP	14.	5.	.56	.22
Real Wages	55.	60.	1.18	1.26
Price Level	16.	16.	1.12	1.12
TOTAL*				
Actual			4.14	2.73
Independent			4.52	3.73

* See footnote 12. The "Actual" risk for the total is the risk of the weighted sum of the different factors. This will differ from the weighted sum of the risks of different factors shown on the "Independent" line because of correlations between the risks of different factors.

Note on units: The weights in columns (2) and (3) are the shares of the factors in the total budget, in percent, as shown in equation (3) for research universities or (6) for small colleges. The total impacts in columns (4) and (5) are derived by multiplying the weight of the factor times the volatility of the factor, where the latter is shown in column (4) of Table 6. The units of the impact are standard deviations of the logarithm of the income-expense ratio. Therefore, the standard deviation of the income-expense ratio for universities over a three-year horizon is 4.14 percent. The variables are defined in Table 1.

Table 9

Frequency of External Shocks to Colleges and Universities

Size of Shock	Historical frequency: number of occurrences, 1954-87 Research University	Small College
More than 5 %	3 years	0 years
3% to 5%	2	5
1% to 3%	9	8
-1% to 1%	5	7
-3% to -1%	9	12
-5% to -3%	4	2
Less than -5%	2	0
Total	34 years	34 years

Source: From calculations of the forecast errors of the logarithm of the income-expense ratio.

Table 10

Actual and Theoretical Frequency of Shocks to Colleges and Universities

Number of occurrences, Based on estimated risk and normal distribution of shocks and on the historical frequency, 1954-87

Size of Shock	Research University		Small College	
	Theoretical	Actual	Theoretical	Actual
More than 5 %	12 %	9 %	5 %	0 %
3% to 5%	12	6	10	15
1% to 3%	17	26	21	23
-1% to 1%	18	15	28	21
-3% to -1%	17	24	21	35
-5% to -3%	12	6	10	6
Less than -5%	12	12	5	0
TOTAL	100 %	100 %	100 %	100 %
Frequency of "Large" and "Severe" Unfavorable Shocks				
Less than -3%	24 %	18 %	15 %	6 %
Less than -5%	12	12	5	0

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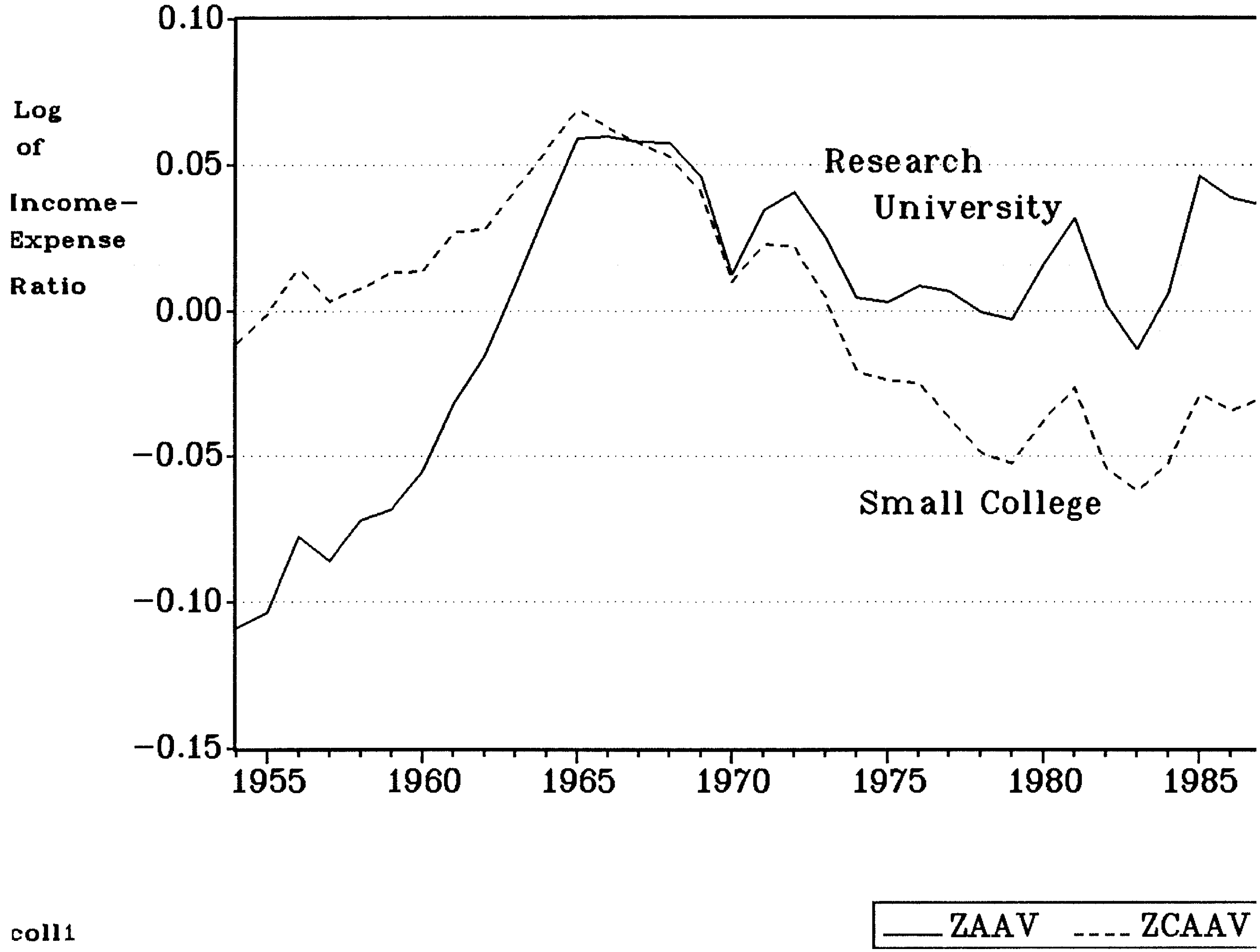
[coll0817]

Figure 1. Financial Factors Affecting Higher Education

[Natural Logarithm of Income-Expense Ratio]



coll1

Figure 2. Forecast Errors of Income-Expense Ratio, 1954-1987

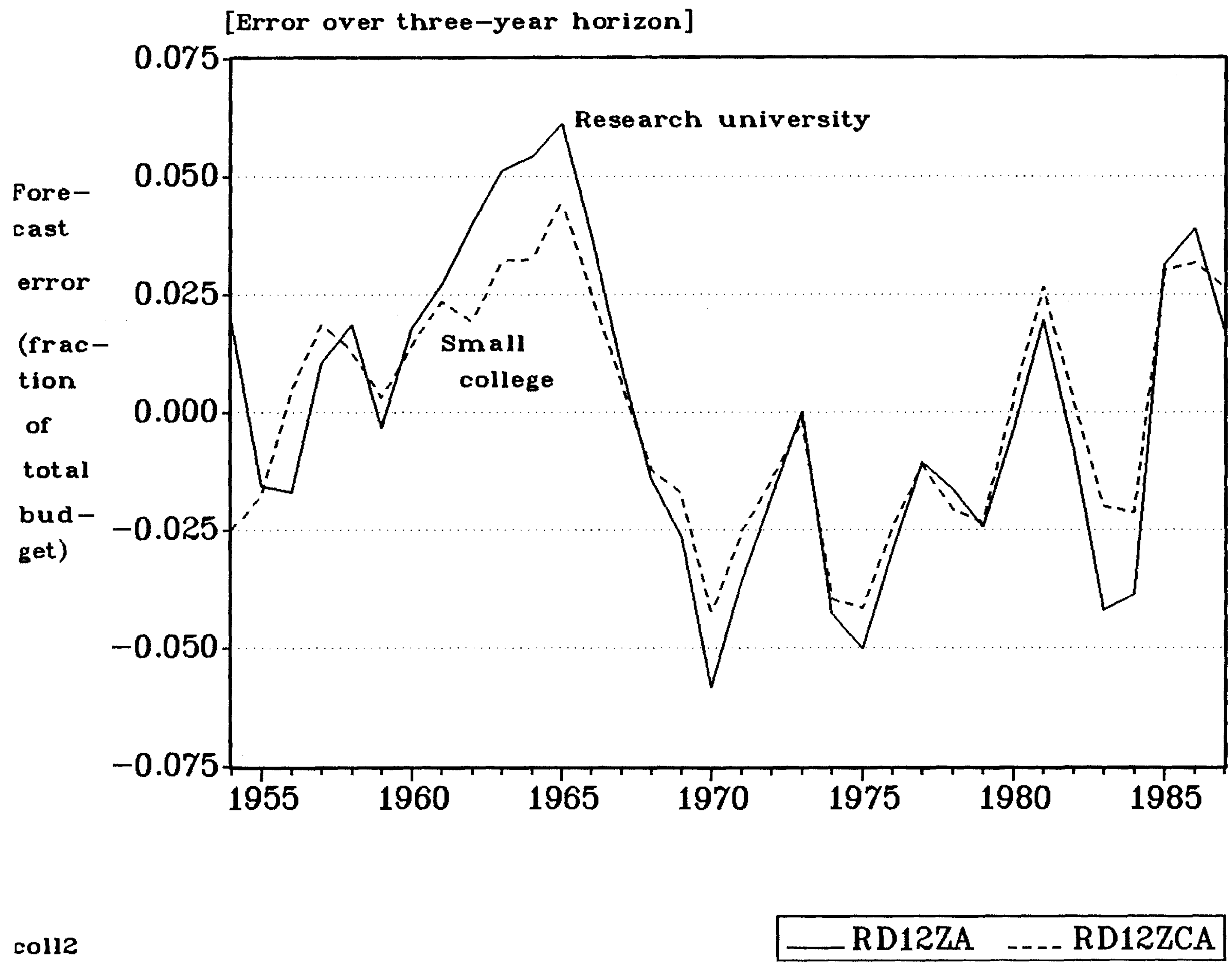


Figure 4. Uncertainty on Colleges

[Total and its Components] collfig4

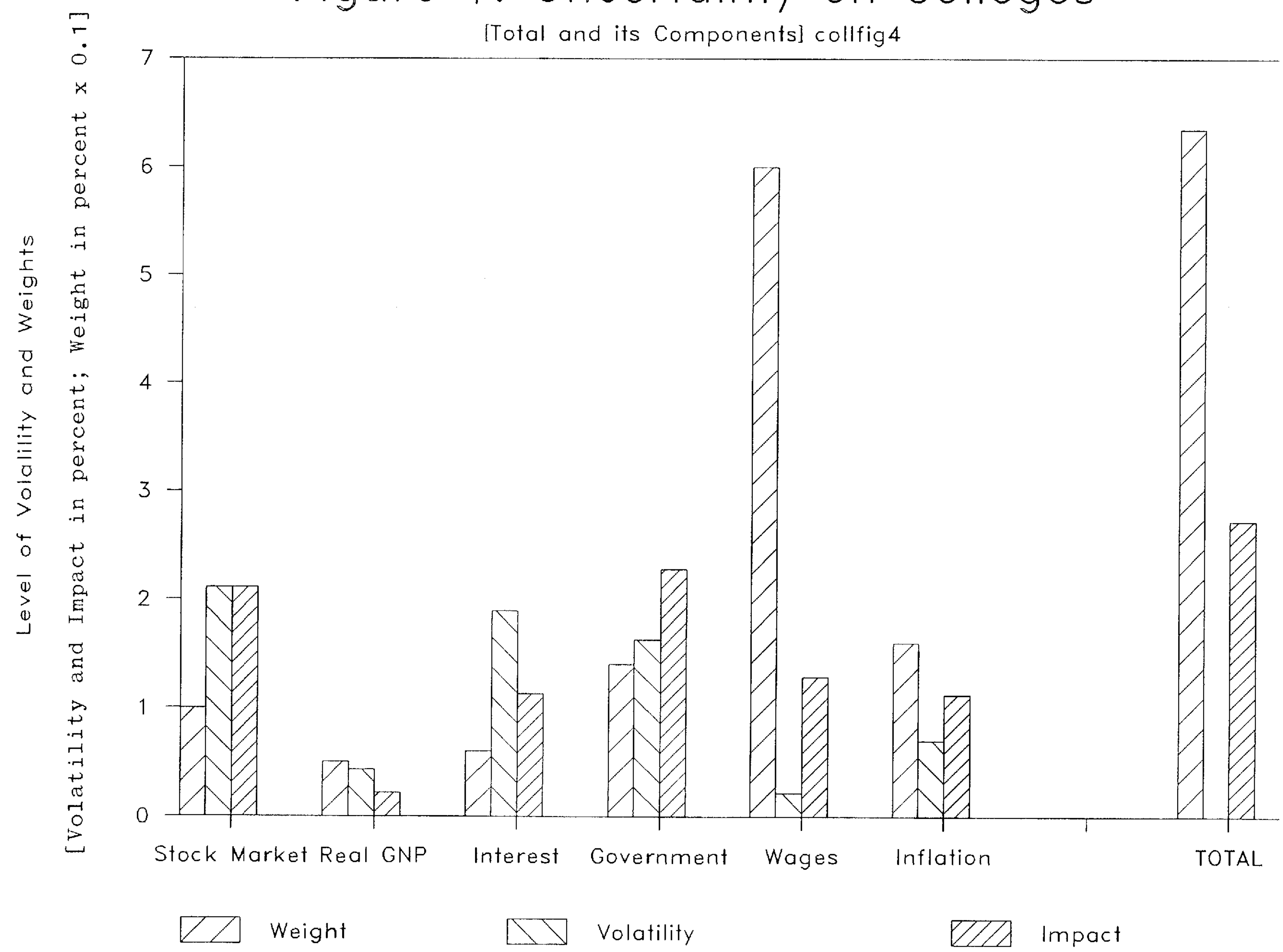


Figure 3. Uncertainty on Universities

[Total and its Components]