TITLE: IS ECONOMETRIC MODELING OBSOLETE?

AUTHOR: Mr. Oakley E. Van Slyke

Mr. Van Slyke is Consulting Actuary with Warren, McVeigh and Griffin. He receives his FCAS in 1980 and is a member of the American Academy of Actuaries. Lee holds a B. S. degree from the Massachusetts Institute of Technology.

REVIEWER: Mr. Michael Fusco

Mr. Fusco is Vice President-Actuary, Personal Lines for Insurance Services Office. Mike has a B. S. in Mathematics and a J.D. from Fordham Law School. He received his FCAS designation in 1976 and is a member of the American Academy of Actuaries. He currently serves on the CAS Examination Committee and is editor of the CAS yearbook.

IS ECONOMETRIC MODELING OBSOLETE?

Econometric models are widely used to forecast economic events. A number of macroeconometric models are well known, including those of the Wharton School, Chase Econometrics, Data Resources, Inc., and the Federal Reserve Bank of St. Louis. Less imposing models are cropping up in all walks of life. The Insurance Services Office (ISO) is studying the application of econometric models to actuarial problems. Because of the effect these models have on our lives through government planning, and because of the possible effect they may have on our livelihoods if they become standard actuarial tools, it is wise for us to understand what econometric models are, why they are increasingly popular, and why they may be only a precursor of even more dramatic changes to come.

For the purposes of this paper an econometric model is a mathematical representation of economic relationships using linear equations. A model may consist of one equation or of many. As an example of a model with one equation, one might represent the relationship between bodily injury loss costs, wages and medical prices using

$$Y_t = C \cdot W_t + C \cdot M_t$$

where

Y_t = Average Claim Size for Bodily Injury Claims at Time t

W_t = Wage Index at Time t

M_t = Medical Index at Time t

C_1, C_2 are constants, usually set to reflect historical data about Y, W and M

In an econometric model the dependent variable (such as average claim size) and the independent variables (such as wages and medical costs) are represented by time series. These time series are usually observed values taken at regular intervals over time. The variables may also be the changes in time series, in either absolute or percentage terms.

Econometric modeling, therefore, refers to a particular way of describing economic relationships. Econometrics, on the other hand, refers to the broader arena in which quantitative methods are applied to economic problems. All of the techniques discussed here are within the field of econometrics, and all are models. The term "econometric model," however, commonly refers only to the type of model described above. We will continue that common usage here.

HISTORY

Paul Samuelson (12) has traced the history of macromodels for over 40 years. Macromodels are models which attempt to encompass all of the major relationships in a particular economy. Although the earliest model cited by Samuelson was the effort in 1932 by Ragnar Frisch, Samuelson says that Jan Tinbergen's model of the Dutch economy in 1935 was the "fountainhead and source." Macromodels were used in the 1940's to describe and prescribe wartime and post-war development and planning. Today's major macromodels were begun in the 1950's and 1960's and revised as theory and conditions changed.

Simpler models, like the model of average claim size given above, have an even longer history. These models are applications of linear regression. Linear regression methods date back to the turn of the century.

Quite often these simple econometric models rely heavily on the relationship between the dependent variable and a measure of time. This is done because the dependent variable cannot be forecast until the independent variables have been forecast and any errors in the forecasts of the independent variables will affect the forecast given by the model. This error problem doesn't exist if time is used as the independent variable. On the other hand, forecasts of various economic indices have become more readily available during the 1960's and 1970's. As a result, simple models based on these indices have become more popular in the past few years.

Simple econometric models have been advocated and employed by casualty actuaries during the 1960's and 1970's. Masterson (8) set forth a number of claim cost indices in 1968. He has periodically written about these indices to keep them up to date. They are weighted averages of various published cost indices. The weights are set by judgment, not by regression (least-squares) techniques.

Finger (1) has suggested various mathematical models of loss costs for which the parameters were to be found by a method of least squares. He suggested as an independent variable a sort of operational time (fraction of claims closed) as well as time itself.

In 1974 Lommele and Sturgis (6) published models of aggregate premium and loss statistics for workers' compensation. They used a conceptual framework in which the independent variables were time series taken from macroeconomic models and insurance industry statistics. Time was not one of the independent variables. Parameters (the c_i's in the average claim cost model above) were found by a least squares method. This approach is being pursued by the ISO as a possible ratemaking step for some lines of insurance. The papers by Masterson and Lommele and Sturgis are now listed in the Recommendations for Study for the examinations given by the Casualty Actuarial Society.

ADVANTAGES

Econometric models have a number of advantages over less mathematical forecasting methods. Arthur M. Okun (10) listed the following advantages in his discussion of macromodels:

1. The objective framework permits the organization of a team effort with a division of labor.
2. The mathematical interrelationships in the model result in a consistency among the component elements of the forecast.
3. The reproducibility of the forecast permits the model user to conduct a post mortem analysis to identify the causes of poor predictions.
4. The objectivity of the forecast is itself desirable.
5. Because the steps leading to the forecast are documented, the model provides for a cumulating of knowledge.

6. The models are labor-efficient because a computer can be used for the routine calculations.

The ISO suggests that its simple models have at least the following additional advantages:

1. They should produce better forecasts than other techniques because they are more sophisticated.
2. The objectivity of the forecasts should make them more acceptable to regulators.
3. The use of non-industry data should lead to:
   - More credibility to the layman
   - A more defensible explanation of cost changes
   - Earlier warning of turning points in the time series being projected
   - Greater accuracy because the non-industry data is generally more current than data about losses.

SUCCESSES AND FAILURES

Econometric models have disadvantages as well as advantages. The history of econometric models includes both successes and failures.

Sophisticated macromodels have had their share of successes and failures. As Samuelson noted, "The famous consensus forecast by government economists of great post-war unemployment did not advance the prestige of the method." The simultaneous increases in inflation and unemployment in 1975 and 1976 (and perhaps late 1979) are not explained by the major macromodels. Samuelson cites a study by Robert Adams of the accuracy of different methods of forecasting the national economy. In Adams's words, "being Sumner Slichter" was apparently better than using any econometric model.

The simpler models now being advocated in actuarial circles have had an even more dismal past. Discussing the models of the U.K. Treasury and Britain's National Institute of Economic and Social Research, Ramsey (11) noted that the models showed "no tendency to improve over time." These models were characterized by their simple assumptions, by stable patterns in the data over time, and by the use of simple trend relationships. (Ramsey contrasted them to macromodels in the U.S. and the Netherlands. These, he said, tended to improve over time as they became more complex and began to reflect dynamic interrelationships.) One prediction by a member of the Academy will illustrate the dramatic way in which these models have sometimes failed.

To preserve the anonymity of the actuary, hypothetical data will be used here. While the actuary forecasted several time series, we shall forecast only one in our example. The actuary had a time series (dependent variable) over a period of 24 months. He assumed that the dependent variable grew exponentially over time. He used a linearized regression model to project the values for a total period of fifteen years. (A linearized regression model has the form lnY = a + bt.) The regression is shown graphically using hypothetical data in figure I-A. Note that the statistics of the regression indicate a good fit.

The alternative models shown in Exhibit I also fit well. Unfortunately, they lead to radically different forecasts. The indicated range for the predicted values at the end of 15 years is from about 200 to about 200 billion. This is because of the length of the forecast period. Clearly all three models are inappropriate because the month-to-month changes in the dependent variable tell us practically nothing about the changes that will take place in future years.

Similar poor results have been noted in forecasts of medical malpractice costs. I was once part of a three-man team making actuarial projections of the average loss cost per doctor (pure premiums) in a particular state. The projections were made in late 1975; accident year 1976 was being forecast. Sixteen policy years of data were used. Models similar to those described by Finger were applied. The various models projected pure premiums of $7,000, $14,000 and various amounts in between. Again modeling failed to provide a useful prediction. At least in this case the indicated range was useful.

The track record of econometric models suggests that they cannot be relied upon to produce useful predictions; some expertise must be applied to the results of the model. As Okun put it, "In fact, virtually nobody takes economic forecasts straight out of a model really seriously as the sole guide to a forecast of the near-term future. Quite apart from filling in the exogeneous variables, every model builder or model user has to adjust equations."

Both Okun and Samuelson regard the forecasts from models as references. Again in Okun's words, ". . . the model as a forecasting device is not an alternative to judgment. It is not a product in and of itself. It is a tool in the hands of a trained economist."

DISADVANTAGES

There are several reasons why econometric models can produce poor forecasts. First, they require accurate projection of the exogeneous variables. Exogeneous variables are those which the model itself does not attempt to predict. In our simple example the exogeneous variables were the wage index and the medical cost index. The projection of average claim cost can be no more accurate than the projection of wages and medical costs.

Second is the index-number problem. Practicable econometric models must incorporate data about the real world in summary fashion. The price of every type of consumer good cannot be fed into the model because the number of consumer goods that can be distinguished from one another is practically beyond enumeration. Instead, the prices of a few representative goods are measured. These components are then combined using some weighting scheme. All the components of an index must be moving the same direction at the same rate, and the weights must be constant and appropriate at all times, or the index will not accurately measure the "average" it purports to represent. It should be clear that no index can in practice pass these tests. This tautology - that index numbers are necessary abstracts that cannot be accurate representations of costs - is called the index number problem.

The third source of error is that the wrong variables might be included in the model. This includes the possibility of leaving out the right variables. In the example of the 15-year forecast described above, it is clear that the actuary left out some important considerations about long-term changes when he made his 15-year forecast. In ratemaking problems it is especially hard to know what variables to include. For example, should the Consumer Price Index be used in rating Homeowners insurance because some Homeowners losses involve consumer goods? Statistical tests can tell us the probability that we will err by removing a certain variable, but no test can tell us if we have included the right variables.

The fourth source of error is that the variables might be interrelated in the wrong way. We may assume that simple relationships are stable, when in fact they are changing. Or we may choose the wrong relationship. There are many to choose from, even if there are only two variables and the dependent variable (Y) is an increasing function of the independent variable (X). For example, the following relationships (and others) are sometimes used:

$$Y_t = a + bX_t \qquad Y_t = aX_t^{\,b}$$

$$Y_t = a + b^{X_t} \qquad Y_t = a + X_t^{\,b}$$

$$Y_t = ab^{X_t} \qquad Y_t = a + bX_t^2$$

$$Y_t = a + bX_{t-1} \quad - \text{ etc.}$$

$$\Delta Y_t = a + b\Delta X_t \quad - \text{ etc.}$$

$$\frac{\Delta Y_t}{Y_t} = a + b\,\frac{\Delta X_t}{X_t} \quad - \text{ etc.}$$

This picture is further complicated when there are two or more independent variables.

In this respect, econometric models have been criticized sharply for their inability to deal with the interrelationships of the real world. According to Forrester (3):

> "Our social systems belong to the class called multi-loop nonlinear feedback systems . . . .
>
> "A great computer model is distinguished from a poor one by the degree to which it captures more of the essence of the social system that it presumes to represent. Many mathematical models are limited because they are formulated by techniques and according to a conceptual structure that will not accept the multiple-feedback-loop and non-linear nature of real systems."

System dynamics may provide a way to make models more realistic.

Also, econometric models rarely predict the sudden changes that can sometimes occur. It would be difficult to conceive of an econometric model that would have accurately predicted Iran's GNP in 1979, even from a vantage point in early 1978. Another approach, called catastrophe theory, may be useful for predicting sudden changes.

SYSTEM DYNAMICS

System dynamics is a way of mathematically describing the components of a complex system so as to focus attention on the pressures that build up in the relationship between the components. As an example, consider a simple process of exponential growth in, say, premium. An econometric model would view exponential growth as a relationship between premium and time:

$$P_t = ab^t$$

System dynamics would view this as a relationship between premium at a particular time t and premium at an earlier time:

$$P_t = b \cdot P_{t-1}$$

In this elementary example the econometric model and the system dynamics model would both give the same answer. In practical problems this will not generally be the case.

Once we have removed the limitations on the model relationships that are inherent in econometric models, many economic and social systems can be modeled more realistically. System dynamics provides for non-linear feedback mechanisms in the model. We shall refer the reader to Forrester (3, 4, 5) for a large number of examples and a detailed explanation of why this is so, but a simple example from insurance will illustrate the point.

We are all familiar with the presence of underwriting cycles in our business. Most students of the cycles have observed that losses are growing at a relatively steady rate, while fluctuations in premiums produce most of the cyclical effect. Stewart (13) has explained the mechanisms involved:

> "Like farmers, insurers meet a fairly constant demand for what they sell. Even more than farmers, they can vary the amount they sell rather finely and quickly. Later on they may not like what was done with prices, underwriting and so forth - any more than farmers like what happens to their prices when they all plant fencepost to fencepost. But the decision to change supply can be carried out . . . .
>
> "For the main lines of insurance and for the industry as a whole, we can call the turns in the underwriting cycle quite reliably two years in advance . . . .
>
> "Even when warned, the individual insurer is trapped. He can only lower prices in advance if willing to smooth the cycle by giving up profits before the top. He can only raise prices in advance if willing to give up customers before the bottom. Either one is asking a lot of human nature and even of good business sense."

Econometric models (in the common use of the term) cannot deal with this behavior. System dynamics is specifically designed to deal with feedback mechanisms like this. The propensity to raise supply when reports of profits are received and reduce the supply when reports of losses are received is a feedback mechanism.

The feedback loop for the underwriting cycle is shown in Exhibit II. As the supply of insurance is increased faster than the demand grows, profit falls. When current profits are falling from black ink to red, insurers have the maximum accumulated profit. This is one pressure to reduce rates. As losses cut into accumulated profits, the insurer's capacity is reduced and it begins to restrict the supply of insurance. Restrictions are tightest when accumulated profits are at a minimum. An accurate model would also reflect the effect of financial reports showing unprofitable underwriting results, and perhaps the current practice of using five years' of trended data in a standard rate filing.

Models that allow for negative feedback predict that cycles will occur. In general, the response to a stimulus will be greater than is needed over the long term, and the system will overshoot its best long-term values. It will then respond to this error by overshooting in the other direction. The results will be patterns like those in Exhibit III. Exhibit III shows the patterns in theory and an example from medical malpractice.

It is important to contrast this type of model with econometric models. The model for workers' compensation written premium suggested by Lommele and Sturgis was:

$$WPREM_t = 289{,}184 + 5{,}687.23(WAGE_t)(PC_t)(RATE_t)(WO_t)$$

where

$WPREM_t$ = Written premium in year t.

$WAGE_t$ = Wages and salaries disbursed in billions of dollars in year t.

PC_t = Percent of the work force covered by workers' compensation in year t.

$RATE_t$ = Average countrywide rate level index in year t for workers' compensation including law amendments.

WO_t = A wage offset calculated to reflect the effect of payroll limitations for year t.

Clearly this model does not explicitly include any provision for changes in the supply of workers' compensation insurance. This is not merely a peculiarity of the model suggested by Lommele and Sturgis, but is a characteristic of the type of model commonly meant by the term "econometric model." As Lommele and Sturgis point out, future values of $RATE_t$ must be supplied by the analyst and are not produced by the model itself. The analyst can reflect in his estimate the effect of past values of $RATE_t$, but this is beyond the scope of the model. System dynamics is designed to bring these considerations within the scope of the model so they can be made explicit.

The history of system dynamics illustrates the major advantages and disadvantages of the approach. The first applications were in the physical sciences. The distance from the Earth to the Sun is the result of the effect of a feedback mechanism (the law of conservation of energy) on the movement of the Earth. This distance varies regularly as in curve C of Figure II-A. Radio squeal, the high-pitched sound one hears when changing stations, is the result of explosive negative feedback as in Curve A of Figure II-A. The Automatic Frequency Control on FM radios is an example of a damped cycle, like that of Curve B. Fluctuations in the radio's tuning are damped out by this circuit. System dynamics obviously works well when the real world can be modeled accurately.

The first applications to economic problems were for manufacturing firms. Inventories, employment levels, orders in process, rates of delivery and other variables were successfully modeled using system dynamics. The success was less complete than it had been for physical systems, of course. It was more difficult to identify the correct interrelationships in the industrial firm. Nonetheless, interviews often developed the necessary information about why orders were placed, why people were hired for overtime or laid off, and so forth. According to Forrester (4), this application, called industrial dynamics, has been generally successful.

System dynamics has also been applied to the economies of several cities, to the production sector of the U.S. economy, and to the world economy [c.f. Forrester (3), Mass (7) and Forrester (5)]. These applications have been useful in identifying the counter-intuitive behavior of social systems. For example, in a discussion of urban dynamics Forrester (3) observed, "To try to raise quality of life without intentionally creating compensating pressures to prevent a rise in population density will be self-defeating."

Nonetheless, system dynamics has been much less useful in producing practical recommendations for such social systems than for industrial systems.

The major reason for this lack of success appears to be that the predictions of the models are sensitive to the assumptions of the model. Also, the limited experience of the builders of systems dynamics models has not been enough to develop a set of assumptions with which most planners will agree. Forrester (3), for example, appears to assume that an increase in the quality of life will lead to an increase in population, if all else is equal. Yet many demographers have observed social systems in which a rise in the quality of life was associated with a decline in birth-rates to replacement levels or below. Another assumption that Forrester (3) made in his study of world dynamics was to include medicine and public health as a part of industrialization. At the same time, he assumed that increased industrialization would lead to increased pollution and, in turn, to a decline in public health. It is unlikely that an increase in medicine and public health would directly increase pollution and ill health.

Second, the model framework for system dynamics predicts only a few types of sudden responses. Other types of sudden responses may take place that cannot be modeled using system dynamics. These have been more accurately modeled using catastrophe theory.

In spite of the shortcomings of several recent applications, system dynamics models are better than econometric models in certain circumstances. One major area of use is in modeling parts of the insurance business that are characterized by negative feedback mechanisms. Underwriting is one example; insurers tend to increase the supply of insurance when they are receiving feedback that their capacity is at an unusually high level even though the resulting new business may be unprofitable. This happens for individual lines such as medical malpractice as well as for insurance in total.

Also, system dynamics models may be more useful than econometric models if they provide a more accurate abstraction of the real world. Models should teach as well as predict. If the limited model structures of econometric models are not instructive, the more flexible structures of dynamic models may provide the desired insight. For example, the model $Y_t = ab^t$ may give the same prediction as the model $Y_t = bY_{t-1}$, but the latter may make the growth process more clear.

CATASTROPHE THEORY

Catastrophe theory is a mathematical model of some common types of catastrophes. For the purposes of this theory, a catastrophe is a special kind of event or result: an abruptly changing effect resulting from a continuously changing force. There is a catastrophe in the making whenever the straw can break the camel's back. An example from Zeeman (15), with due credit to Conrad Z. Lorenz, is of aggression in a dog. As Van Slyke (14) wrote:

> ". . . . It can be observed that gradually increasing fear in the emotional make-up of a slightly angered dog will result in only a slight change in that dog's behavior. (We assume here that the dog is not angry enough to attack.) This gradual change will continue until at some level of fear the dog will suddenly turn and flee; that is, the increasing fear will at some point cause a sudden change in the behavior of the dog. This special type of catastrophe is only roughly similar to our usual uses of the word. For example, bridge collapses and buffalo stampedes are catastrophes in either sense of the word; an outbreak of a contagious disease would not be a catastrophe covered by this theory."

In catastrophe theory the dependent variable may be abruptly changing. The independent variables, on the other hand, are changing smoothly. In the case above, the independent variables were fear and rage or anger. An attractor is analogous to a dependent variable, but can include a whole set of behavior attributes. It is a stable or equilibrium state of behavior. For example, at a certain level of both fear and rage, the dog had one stable pattern of behavior: to stand snarling; or to flee; or to do something else.

Van Slyke cites as an even clearer example of an attractor an example Zeeman gives of tropical fish:

> "Some tropical fish exhibit territorial behavior, building nests, defending these nests from foes and using them as sanctuaries. A fish of this type, if foraging away from its nest, would flee from a larger fish. It would continue to flee until it reached an unseen boundary near its nest that we call its defense perimeter. Upon reaching the defense perimeter, the fish would turn and defend its nest. Similarly, a fish near its nest would defend that nest out to what we might call an attack perimeter. There is a pattern of behavior that causes the fish to turn and defend when it reaches the defense

> perimeter and that causes the same fish to advance and attack so long as it stays within its attack perimeter. That pattern of behavior is an attractor. Although other behavior might be exhibited by the fish, the attractor is far and away the behavior that is most likely."

Catastrophe theory can be illustrated with an insurance example. Consider the insurance or self-insurance of losses. A move to self-insurance often results in a rapid reduction of insurance premiums by 50% of more. As the costs of using insurance to provide for losses increase with the growth of a business, the business is more and more likely to establish a self-insurance program. Usually the business will not establish the self-insurance program until well after the time that self-insurance becomes financially advantageous. Then it will keep the self-insurance program, even if the financial advantages diminish (perhaps because of a softening of insurance markets or a reduction in the size of the business).

Catastrophe theory can be useful in describing situations having five particular qualities. First, a catastrophe exhibits behavior that has two likely states. In the case of self-insurance, the likely states are insurance and self-insurance. Second, a catastrophe exhibits sudden transitions between these states. The transition to self-insurance takes place on one particular day when the amount of insurance is reduced. Third, in a catastrophe the place of the transition between the states depends upon the direction that the behavior is changing. For this reason, the financial advantage required to begin a self-insurance program is less than that required to continue it. A fourth quality of catastrophes is that they lack a middle ground of behavior. Usually a significant self-insurance retention is taken, if any. The fifth and last quality of catastrophes is that a very small change in the initial conditions can result in a very large change in behavior. For example, if a business felt that the costs of insurance were great, a slight rate increase could trigger a move to self-insurance. If, on the other hand, the business had been satisfied with its insurance, the same rate increase (or the same resulting rate level) could produce no change at all.

Econometric models, system dynamics models, and catastrophe models can be contrasted by imagining the possible values of the dependent variable as points on a surface. Exhibit IV attempts to illustrate the major differences between the three approaches, without attempting to provide any further explanation of theory.

Exhibit IV-A illustrates the basic premise of econometric models: that things will continue to change according to some preordained pattern. Every movement in the independent variable produces a change in the dependent variable according to a preset relationship. The relationship is embodied in the surface shown in the exhibit.

In system dynamics models, all of the variables are functions of time and of one another. Imagine a marble rolling along a trough (see Exhibit IV-B). The height and sideways displacement of the marble, and the speed of the marble in each direction, are tied together in a relationship that does not change over time. In the case of a marble rolling in a trough, these factors are related by physical laws dictating that the total energy of the system is constant. If energy is removed from the system (perhaps by friction), the marble's path will be a damped cycle. If energy is added (as a child pumps a swing), the marble's path will be an explosive cycle. Of course, economic models are much more complicated than this example.

In catastrophe models, the dependent variable depends on the values of the independent variables and the past history of the system. The interrelationships are visualized as a folded surface. In the path shown in Exhibit IV-C, a catastrophic drop in the dependent variable has occurred when changes in the independent variables have moved the system over the edge of the fold (solid path). Had the independent variables changed in a different way (dotted line), the same final values would have been reached for all variables without a catastrophic change. Also, the same values of indepedent variables can be associated with different values of the dependent variable, as illustrated by points A and B. Whether the dependent variable will be at A or B depends on the history of the independent variables.

Zeeman mentions uses of catastrophe theory in the fields of behavioral science, as indicated by these examples, and biology, physics, engineering and the development of a science of language.

Catastrophe theory is new. Although it hasn't been used in insurance, it should be useful whenever the five qualities of a catastrophe are present. The field is so wide that examples come easily, e.g., the formation of captives and doctor-owned insurance companies.

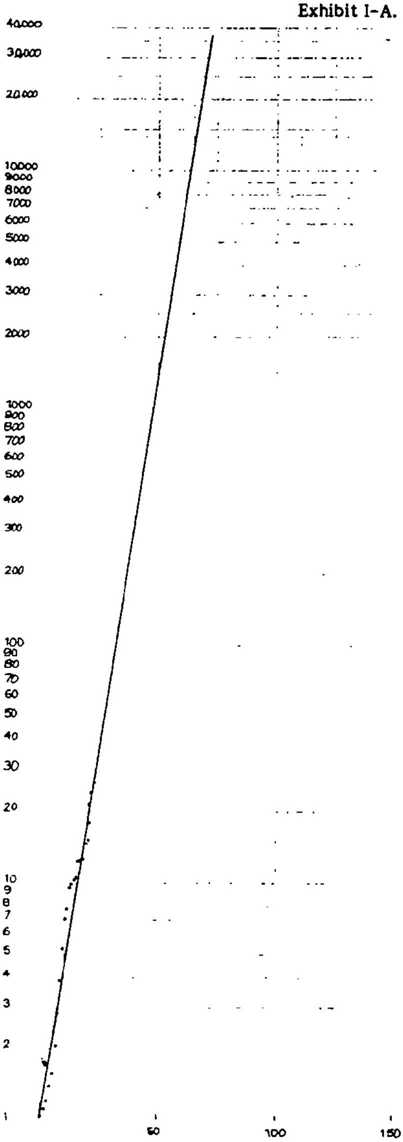
CONCLUSION

Econometric models are useful tools for actuaries. They can offer many advantages, especially when used as a tool in short-term forecasting. These advantages include their objectivity, which permits a division of labor, greater credibility with regulators, and cumulating knowledge; mathematical explicitness, which allows the analyst to identify the causes of poor predictions, efficient use of computers and a consistency among the elements of the forecast; and the use of non-insurance data, which provides more credibility with laymen, a more defensible explanation of cost changes, possibly earlier warning of turning points, and greater accuracy by reducing the analyst's reliance on immature loss data. Econometrics is not obsolete.

Nonetheless, it is not the most sophisticated forecasting tool available. The best model is the one that best represents the relevant qualities and relationships in the real world. This may be an econometric model. But in some problems it is important to recognize that the variables are all interrelated, and that a change in one causes feedback to the others. In other problems it is important to recognize that catastrophic change can occur, and that the effect of the economic environment may depend on the history of that environment. In these cases, the more sophisticated models of system dynamics or catastrophe theory may be better than econometric models.

Most important of all, the models are just tools. Because they will always fail to recognize the complexities of the real world, they must be just a part of the forecasting process, not a replacement for it.

Exhibit I-A.



Regression Equation:

$Y = 1.050 \cdot 1.156^{x}$

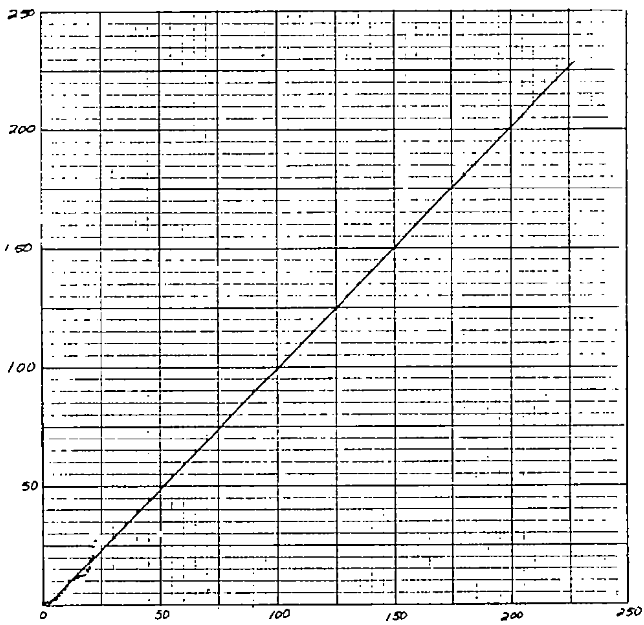
$R^2 = .938$

$s^2 = .07$

F - score = 332.7

Projection for x = 180:
$y = 2.2574 \times 10^{11}$

Exhibit I-B.



Regression Equation:

$Y = -3.155 + 1.030x$

$R^2 = .934$

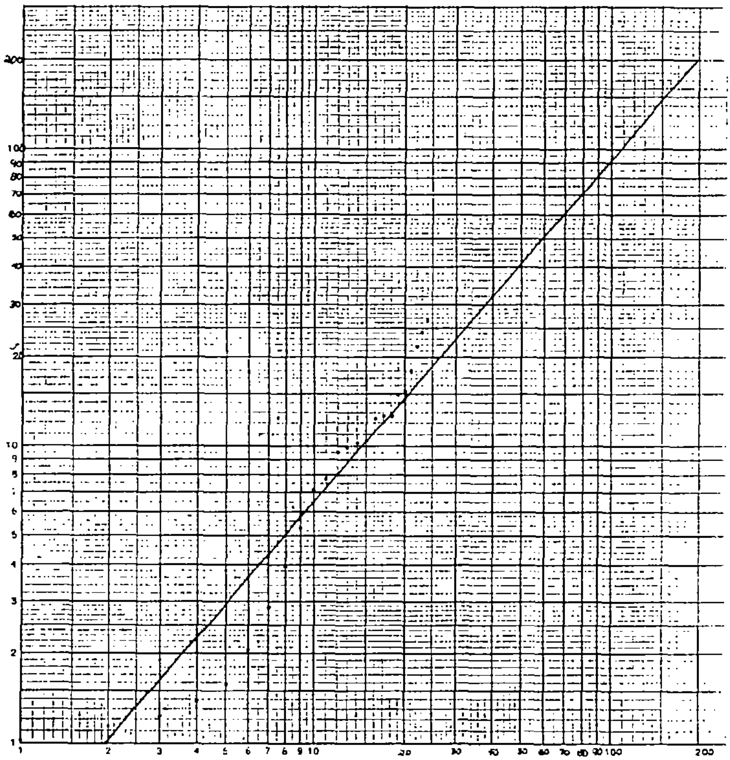
$s^2 = 3.92$

F - score = 311.7

Projection for x = 180:

y = 182.32

Exhibit I-C.



Regression Equation:

$Y = .467 \cdot x^{1.1475}$

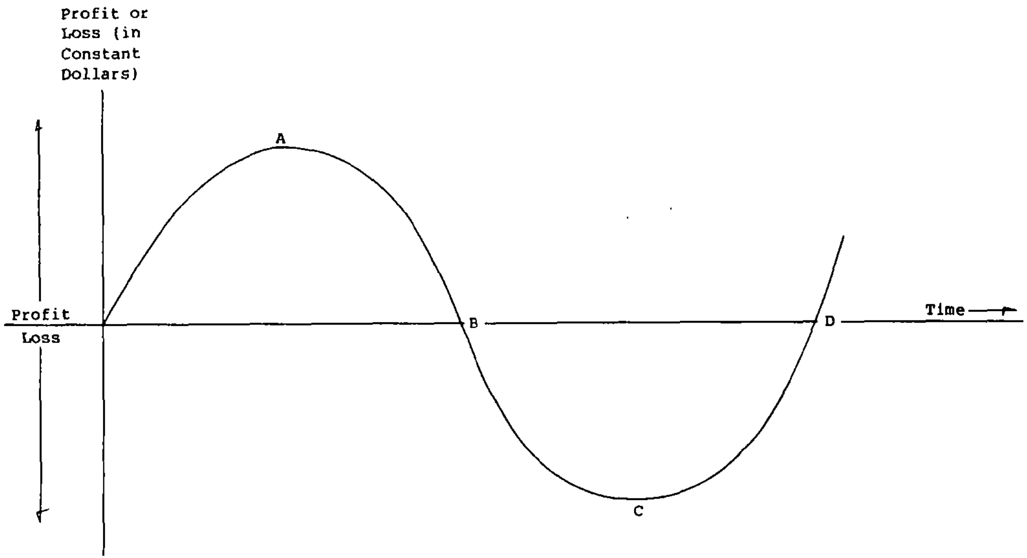
$R^2 = .860$

$s^2 = .16$

F - score = 134.6

Projection for x = 180:
y = 180.82

Exhibit II



A Maximum Profit

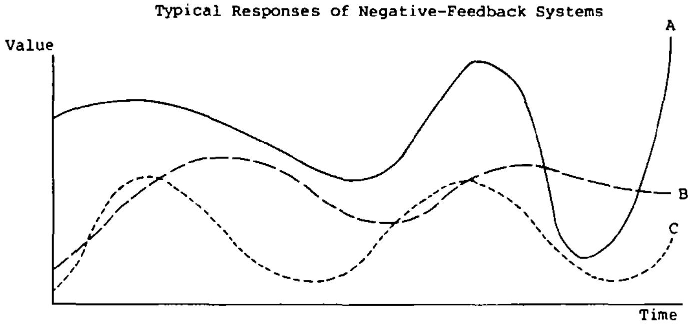
B Maximum Rate of Rate Cutting at Time of Highest Accumulated Profit

C Minimum Profit

D Maximum Rate of Increase in Rates at Time of Lowest Remaining Accumulated Profit

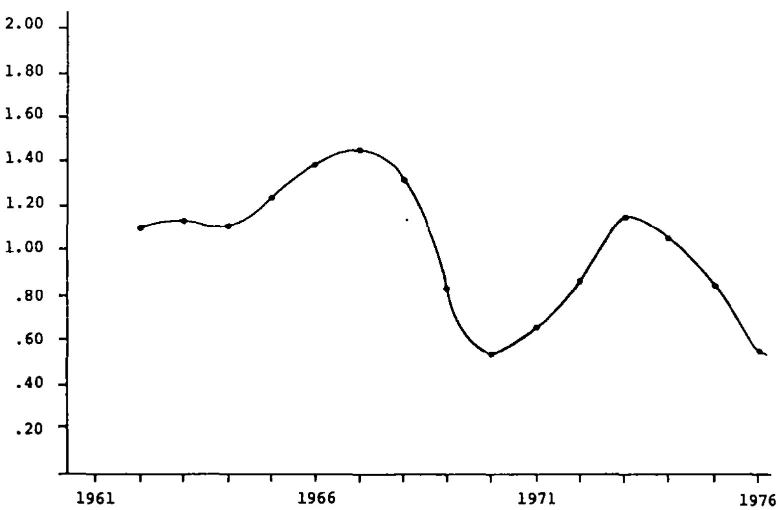
Exhibit III

Exhibit III-A.
Typical Responses of Negative-Feedback Systems



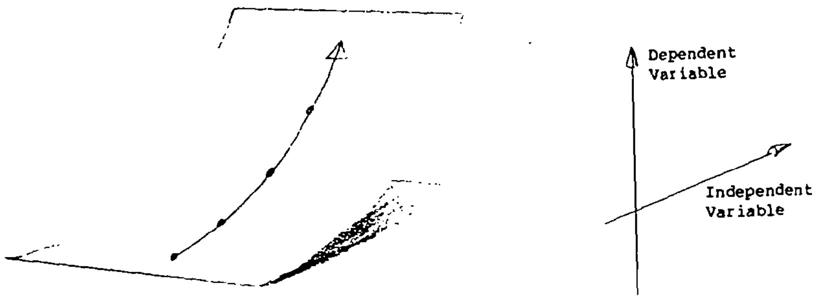
Cycles Can be Explosive (A), Damped (B) or Steady (C).

Exhibit III-B.
3-Year Average Loss Ratios for Medical Malpractice, 1961-1977
(One Carrier in One State)

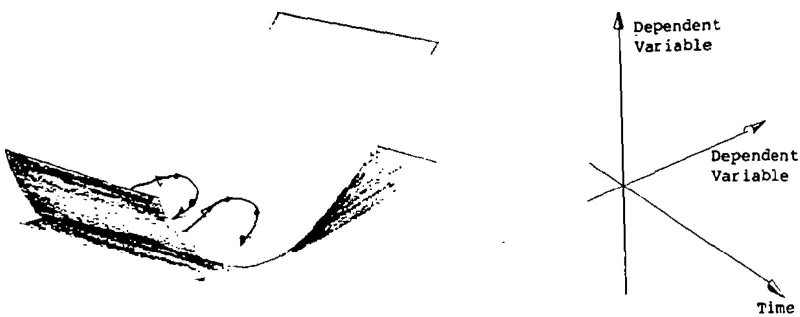


Three-year averages are shown because the insurer's underwriting policy did not change as often as annually. Also, the small volume of losses masks this pattern if individual years are considered.

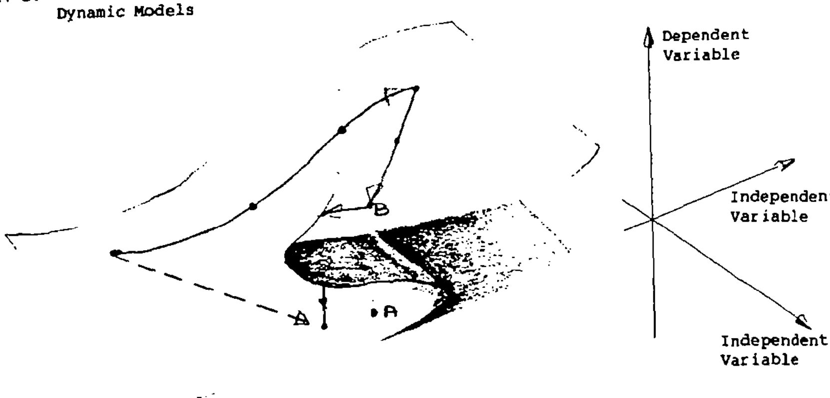
Exhibit IV



IV-A. Surface of Opportunities in Econometric Models



IV-B. Surface of Opportunities in System Dynamic Models



IV-C. Surface of Opportunities in Catastrophe Theory

REFERENCES

1. Robert J. Finger, "Modeling Loss Reserve Developments," PCAS LXIII, 1976, p. 90.

2. Jay W. Forrester, "Changing Economic Patterns," Technology Review, August/September, 1978.

3. Jay W. Forrester, "Counterintuitive Behavior of Social Systems," Technology Review, January, 1971.

4. Jay W. Forrester, Principals of Systems, Second Preliminary Edition, Wright-Allen Press, Inc., Cambridge, Mass., 1968. (Distributed by M.I.T. Press, Cambridge, Mass.)

5. Jay W. Forrester, World Dynamics, M.I.T. Press, Cambridge, Mass., 1971.

6. Jan A. Lommele and Robert W. Sturgis, "An Econometric Model of Workmen's Compensation," PCAS LXI, 1974, p. 170.

7. Nathaniel J. Mass, "Modeling Cycles in the National Economy," Technology Review, March/April, 1976.

8. Norton E. Masterson, "Economic Factors in Liability and Property Insurance Claim Costs 1935-1967," PCAS LV, 1968, p. 61.

9. Charles L. McClenahan, "A Mathematical Model for Loss Reserve Analysis," PCAS LXII, 1975, p. 134.

10. Arthur M. Okun, "Uses of Models for Policy Formulation," in The Brookings Model: Perspective and Recent Developments, Gary Fromm and Lawrence R. Klein, eds., American Elsevier Publishing Co., Inc., New York, 1975.

11. James B. Ramsey, Economic Forecasting - Models or Markets, Hobart Paper #74, Institute of Economic Affairs, London, 1977.

12. Paul A Samuelson, "The Art and Science of Macromodels Over 50 Years," in The Brookings Model: Perspective and Recent Developments, Gary Fromm and Lawrence R. Klein, eds., American Elsevier Publishing Co., Inc., New York, 1975.

13. Richard E. Stewart, "Profit, Time and Cycles," address to the C.A.S., May 21, 1979.

14. O. E. Van Slyke, "Catastrophe Theory," published in John B. Reid, Jr., "Fits and Starts," Best's Review, Life and Health edition, approximately February, 1977.

15. E. C. Zeeman, "Catastrophe Theory," Scientific American, April, 1976.