Introduction to the Use of Econometric Models in Economic Policy Making

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Foreword

Econometric models and economic forecasting are enigmas to most of us. In this publication authors Miller and Kaatz refreshingly cut through mystery and ceremony to provide readers with a description of econometric models and some of the ways they can be used by economic policy makers.

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We think the discussion will be of value to beginning level economics students and instructors as well as to interested laymen. We are proud to make it a part of our Economic Information Series and pleased to contribute to economic literacy in this specialized area.

B. K. MacLaury
President

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Forecasting and the Economic Environment

Forecasting is an important part of the economic policy-making process. This paper introduces readers with little or no background in economics and mathematics to the use of econometric models in forecasting for policy making purposes. Section I attempts to define a forecast and in section II a small but sensible model is constructed and applied to a simplified policy-making problem. Section III deals with the nature and application of more realistic large scale models.

What is a Forecast?

One forecast familiar to parts of our country is: "two inches of snow are expected to fall tomorrow." People know from experience that maybe two inches will fall the next day, or maybe eight inches, or maybe none. Most people correctly interpret the announcement in approximately the following way:

Given atmospheric conditions observed at this time, an accumulation of about two inches of snow is the most likely outcome for tomorrow.

Weather forecasters have data on current wind speed and direction, temperature, barometric pressure and other climatic variables. From meteorological theory and analysis of past weather data, they have constructed forecasting models, that is, sets of relationships connecting currently observed conditions with the most likely weather outcome for the next day (Figure 1a). Models tell them that when atmospheric conditions similar to those presently observed developed in the past and persisted for a period of time, then most often it snowed about two inches the following day (Figure 1b).

Suppose it doesn't snow at all. What went wrong with the forecast? First, the historical data and assumptions fed into a model can be checked. Even a "correct" model cannot predict well unless it is provided accurate input data and assumptions; models produce forecasts that are conditional on the inputs. Or a model itself may be faulty, a possibility not easy to evaluate. A given model may forecast acceptably well under certain conditions but poorly under others. Last — a less obvious caveat — a model may have correctly identified the most likely outcome only to have a less likely outcome occur. This is important. A complete forecast is really a statement of all possible outcomes along with the probability that each will occur. Few forecasts are presented in this full detail. Meteorologists have taken a step in that direction by attaching probabilities to some predicted outcomes, for example, "... a 75% chance of measurable precipitation..." To summarize, a particular forecast may not be realized for a variety of reasons:

- The input data on current weather conditions may be incorrect.
- The assumptions on which the forecast is based may not materialize.
- The forecasting model itself may not be correct.
• The most likely outcome may in fact have been correctly predicted only to have a less likely outcome actually occur.
• Some combination of the above.

Economic Forecasts
Economic forecasters plod largely the same path as meteorologists but with greater trepidation. Economic data are subject to many more errors and revisions than usually found in the physical sciences. Assumptions necessary to produce an economic forecast are difficult to make. What will federal tax and spending policies be during the forecast period? How will international events affect the domestic economy? Will there be a major strike in one industry or another? And so on.

Probably overshadowing all these problems however is the inherent difficulty in explaining aggregate human behavior. Capturing the essential forces that move the institutions and individuals which constitute “the economy” in a few (or few hundred) equations is very difficult. Economic policy makers must recognize the uncertainties associated with their forecasts and assess their impact on the consequences of policy decisions.

More will be said in section III on evaluating forecast accuracy. Now, before constructing a simple econometric model, it will be helpful to review the environment in which models are built and used.

The Economic Environment
Economic events occur over time. Every day millions of transactions take place, each contributing its share to overall activity. Economists cannot observe, ponder and weigh the importance of each event. Instead, they collect and aggregate sample data which they hope will provide useful measures of all the underlying events. To standardize this information, data are referenced to a time unit. National Income Account data (gross national product and its components) are collected and
published on a calendar quarter basis. Other economic data are available monthly, weekly, daily or even more frequently. Most econometric models are quarterly models.

Figure 2 shows a forecasting time framework. The heavy line moving from left to right represents time. The present is indicated by a vertical line. Economic data are available for the quarter just past and, of course, for many quarters going back into history. The economist’s job is to examine historical data to determine what, if any, persistent relationships can be discovered among the economic variables. How are production, prices and employment related during a particular quarter? How do the hundreds of other economic variables seem to interact? Time is also important because economic events in one quarter depend in part on what happened in previous periods. Employment this quarter is dependent in part on what it was in the previous quarter, perhaps even several quarters ago. Employment this quarter probably also depends in part on what happened to production, prices, and a lot of other things during several past quarters. A good deal of the model builder’s skill is put to work exploiting the continuity of economic events over time. These relationships, when expressed in terms of mathematical equations, are essentially what constitute an econometric model. If the relationships are largely correct in portraying the economic structure and if this structure persists into the future, then the model may achieve some success in predicting future values of the economic variables. So in a somewhat narrow sense an econometric model can be described as . . .

a set of mathematical equations which specify relationships thought by the economist to exist among economic variables — not simply within a particular time period but also from period to period.
Building a Small Econometric Model

The model constructed here is very simple. Only a few variables are used and no relationships are specified which involve dependence from one time period to another. It can be thought of as a quarterly model of the United States economy.

Economists, like most scientists, imagine themselves to be an orderly lot, proceeding methodically in their work toward truth and beauty. This myth will be perpetuated by proceeding as if there were three distinct stages in building a model. In fact, of course, there is a great deal of interrelated effort — backtracking, reworking and teeth gnashing — to produce a functioning product. The first stage involves specifying the structure of the model, which is basically a set of relationships believed to exist among the economic variables. These relationships are written in the form of general mathematical equations. The second stage is estimation of specific numerical values for certain coefficients that appear in the structural equations. For example, in specifying the structure of a model an equation may be written which postulates that people spend some fixed, but as yet unknown, percentage of their income each quarter. Then, in the second stage statisticians estimate the average percentage value that has prevailed during recent years. Statistical methods are applied to all equations in the model to determine values of coefficients which best account for observed past events. And finally, the third stage involves providing systematic and efficient methods to solve the model once the structure is specified and the coefficients estimated. Solve as used here means:

- providing all necessary input data (current temperature, wind speed, etc., in the weather forecasting example);
- providing all necessary input assumptions (assumption that the atmospheric conditions would persist); and
- providing a suitable mathematical method to compute the resultant forecasted numerical values of the economic variables in the model.

Each of these stages will now be discussed in more detail.

Specifying the Structure of the Model

Materials, tools and skill are needed to build most things, and so it is with econometric models. The materials needed to build econometric models are economic variables. As the economic variables for the small model are introduced they will be arranged in related groups or sectors to introduce a first semblance of order. Four sectors will be distinguished: households, business firms, government and a monetary sector represented by the Federal Reserve System (Fed) as the central monetary authority. A pictorial diagram of the small model is shown in Figure 3.

THE HOUSEHOLD SECTOR . . .

- Earns income (\( \$Y \))
- Pays taxes (\( \$T \))
- Spends money (\( \$C \))
- Saves money (\( \$S \))

In the model constructed here, people as members of households perform four functions. They work and earn income — the total value of all people’s income will be labeled \( \$Y \). Second, they pay taxes in the total amount \( \$T \). They spend money, call it \( \$C \) for personal consumption, and they save money in the amount \( \$S \). That is all people as householders can do in this model.

THE BUSINESS SECTOR . . .

- Spends money (\( \$I \))
- Produces all goods (\( \$Y \))

Business firms spend money to build inventories and to add new plant and equipment. Call this \( \$I \) for business investment. Firms in this simple world are also assumed to produce and sell all goods demanded of them. Because of the way economists have constructed the National Income Accounting System, it is true by definition that the total value of all goods produced exactly equals total expenditures by all sectors of the economy, which in turn equals the total income of all persons. The total income variable was previously labeled \( \$Y \) in our discussion of the household sector. To lend plausibility to this accounting convention, think of the sale of a pair of shoes for \( \$5 \). The cobbler, as a businessman, produces and
sells a $5 pair of shoes. As a householder, the cobbler derives $5 of income. And the householder who buys the shoes records a $5 expenditure. Only final sales to the ultimate user of the product are included in these computations in order to avoid double counting. For example, if the cobbler bought leather from a tanner, that transaction would not appear directly in the final summation determining the value of total income.

**THE GOVERNMENT SECTOR . . .**

. . . Sets the income tax rate \((r\%)\)
. . . Collects income taxes \(($T)$
. . . Spends money \(($G)$
. . . Incurs a deficit \(($D)$

Government produces no goods in competition with the business sector. It collects taxes and spends money. Government can choose to spend any amount so its budget may be in balance \((D \text{ equals zero})\), in surplus \((D \text{ less than zero})\), or in deficit \((D \text{ greater than zero})\), depending on the difference between the amount spent \(($G)$\) and tax receipts \(($T)$).

**THE MONETARY SECTOR . . .**

. . . Sets the interest rate \((r\%)\)

The central bank is responsible for determining and implementing monetary policy. The only tool of monetary policy incorporated into this model
is the interest rate at which everyone lends and borrows. The Federal Reserve is assumed to be able to set this rate exactly.

That completes the list of economic variables — materials — available to build the model. The equations defining the model’s structure must be sufficiently complete so that future numerical values of each variable can be predicted. However, they must not be overly complete. If too many equations or other constraints are imposed on the variables, the model is said to be overspecified in which case it is usually not possible to find numerical solutions for all of the variables.

There are two general ways to determine future numerical values of the variables. The first — simple conceptually if not in practice — is to declare the variable *exogenous*. Exogenous means the numerical value is predetermined as far as the model is concerned. Selecting values for exogenous variables is part of the process of providing input assumptions as described earlier. Perhaps economists pick a value according to their own judgment. Some exogenous variables may be predicted by other independent models. Whatever the procedure, future numerical values for all exogenous variables must be provided as input assumptions before the model can be solved to determine forecasted future values of the *endogenous* variables. An endogenous variable, then, is one determined by interactions of the structure of the model. If this terminology is somewhat confusing, push on. The example to follow should help.

If a variable is endogenous (forecasted by the model), then a structural equation must be provided in the model which specifies the particular relationship that variable bears with other exogenous and endogenous variables. Nine variables were introduced above:

- $r$ Interest Rate
- $t$ Income Tax Rate

Three of these will be treated as exogenous. The tax rate ($t\%$) and total government spending ($G$) are both set by the government. The interest rate ($r\%$) is determined by the Federal Reserve System.

Six endogenous variables remain to be explained, so the model must contain exactly six structural equations. Ideally, structural equations take a form based on theoretical economic principles believed by the model builder to be true. Some investigators, however, simply examine a large number of alternative equations, searching for those that best agree with historical data. They say an equation that fits past data better is a better equation. But if the goal is to forecast, that may not be true. A persistent investigator can develop equations which, though they do not make behavioral economic sense, do by happenstance fit past data very well. Forecasting with these kinds of equations will be successful also only by happenstance.

Now to specify the six equations which make up the structure.

**PERSONAL CONSUMPTION AND SAVINGS**

People earn income $\ldots \ldots \ldots \ldots \; Y$

and they pay taxes $\ldots \ldots \ldots \ldots \; T$

That leaves $\ldots \ldots \ldots \ldots \; (Y-T)$

which can be used to spend $\ldots \; S_C$

and save $\ldots \ldots \ldots \ldots \; S_S$

Consumption will be explained by the *behavioral* equation:

**Equation 1**

$$C = m(Y-T)$$

read $C$ equals $m$ times the quantity $Y$ minus $T$.

The equation states that people as a whole tend to spend a fixed proportion of their after-tax income every quarter. The particular numerical value of this proportion is not known yet, so the symbol $m$ is used until later when the value is estimated. The symbol $m$ is a *coefficient* of the equation. The equation does not require that each person spend the same proportion ($m$) of his income. Individual behavior may differ widely. The
equation requires only that, in each calendar quarter, the average proportion over all persons stay at a value close to m. This equation is called a behavioral equation because it is derived from hypothesized patterns of behavior for members in one or more sectors of the model.

The level of savings follows directly from income, taxes, and consumption according to the following identity equation:

Equation 2  \[ S = Y - T - C \]

which says savings are what is left from income after paying taxes and spending for personal consumption. This is called an identity equation because it simply asserts some defined truth about the economy or the accounting system being used. It may be tempting to include another behavioral equation relating the level of savings to the interest rate. For example, people might be expected to save more if the interest rate is increased. But if we attempt to explain both consumption and savings by behavioral equations while retaining equation 2 as an accounting definition of savings, then very likely the three equations (equation 1, equation 2 and the new behavioral equation for savings) would prove to be inconsistent. That is, there would be no numerical values of consumption and savings which could simultaneously satisfy all three equations. This would be an example of overspecifying the model.

BUSINESS INVESTMENT

Business firms rely heavily on loans as a source of funds for investment. Therefore, a plausible economic theory may hypothesize that investment is dependent, at least in part, on the interest rate. Investment in our model will be explained by the behavioral equation:

Equation 3  \[ I = a - br \]

This equation has two coefficients which must be estimated, a and b. The symbol I represents the amount of business investment expected to take place in a given quarter. The equation says investment will be “a” dollars minus “b” dollars times the value of the interest rate (which is assumed to be set by the Federal Reserve). Suppose r is set at a very low value, say even zero percent. Then the value of r in the equation would be zero and investment would be:

\[ I = a + 0 = a \]

In other words, the equation asserts that investment in any particular quarter will not exceed \(a\) no matter how low the cost of borrowing becomes. If the interest rate were set higher, then the equation would predict a correspondingly lower level of business investment. Some economists may not agree with this description of underlying economic principles. They may agree that investment is indeed dependent only on the interest rate but feel this particular form of equation is incorrect. Or, they may believe that investment depends on other variables in addition to the interest rate. However, they may go on to say, over the range of interest rates experienced in recent years, and considering rates expected to occur in the relevant future, the oversimplified equation above is approximately correct and is adequate for the purposes at hand; that additional accuracy is not necessary compared with the effort involved in dealing with a more complex equation. Like consumption, the investment equation expresses an aggregate relation. Individual firms may differ in their investment decision-making procedures, but in each calendar quarter the aggregate result is expected to closely follow this equation.

TAXES AND THE DEFICIT

The world portrayed by this simple model has one tax, a proportional income tax. Government sets the exogenous tax rate (\(t\%). Tax receipts (\$T) are then determined by the identity equation:

Equation 4  \[ T = tY \]

Total government spending (\$G) is also exogenous. The deficit (\$D) then is determined by the identity equation:

Equation 5  \[ D = G - T \]

In specifying the structure of a world with more complex tax systems, it may still be acceptable to use a simple tax equation like the one given here.
The argument would be that the total effect of the various taxes is to produce about the same percentage tax receipts every calendar quarter (as a percent of total income). When a simple tax equation is used to approximate a more complex tax system, however, the value of the percentage tax rate (t) would not be exogenously set but would be a synthetic average tax rate to be estimated from past experience just as the coefficients m, a and b must be.

FUNDAMENTAL ACCOUNTING IDENTITY

One more key accounting identity is necessary to complete the system of structural equations for this little model. It is the formal method used to incorporate the accounting convention discussed earlier which makes total income equal to total expenditures. This identity equation is written:

Equation 6  \[ Y = C + I + G \]

which says total income equals personal consumption expenditures plus business investment plus government expenditures.

The structural equations and their coefficients are summarized in Figure 4. Nine variables were introduced. Three will be determined exogenously. Six endogenous variables will be determined within the model — two by behavioral equations and four by identity equations. Three coefficients of the behavioral equations must be estimated.

Can a model this small be of any value? Properly qualified the answer is probably yes. In order to explicitly address the entire scope of economic phenomena, a model would necessarily be very large. If, however, our interest at the moment centers on a more narrow range of questions, then a properly designed and constructed small model may be useful. Our small model has no equations for prices or employment, hence it cannot provide
information on these variables. It specifically addresses questions concerning relationships between the general level of interest rates and total income, questions which are of particular interest to monetary policy makers.

There is a second reason to construct small models. It is a goal of science to reduce complexity to the smallest number of basic axioms. If a very large and precise model were somehow given to us, economists would set right out to discover its fundamental features. What primary mechanism provides the driving force and basic structure of the model, and what parts represent simply an elaboration of detail or variations of first principles? Small models result from attempts to cut through the ponderous, to determine and express basic structure in concise and useful ways.

Any model is small relative to the real world, but properly constructed and applied it can provide the basis for systematic thinking on economic issues.

**Estimating Coefficients of the Model**

With the structure specified in terms of general equations, the next step is to estimate numerical values for coefficients appearing in the equations. The mathematics of statistical estimation is quite complex. Basically, statisticians attempt to find numerical values for the coefficients which, when used in the structural equations, best account for known historical data. For example, the investment equation...

\[ I = a - br \]

has two coefficients to be estimated, \( a \) and \( b \). Values of investment \( (I) \) and the interest rate \( (r) \) are known for many calendar quarters in the past. If we plot a graph of historical data with investment (the dependent variable) on the vertical axis and the interest rate (the independent variable) on the horizontal axis, we get a "scatter diagram" as shown in Figure 5. When graphed this way, the investment equation is a straight line, the position of which is determined by values of the coefficients \( a \) and \( b \). The statisticians' job is to estimate coefficient values which make the accumulated prediction errors as small as possible.

Suppose statisticians have estimated the model obtaining the following results:

- best estimate of \( a \) = $100 billion;
- best estimate of \( b \) = $120 billion; and
- best estimate of \( m \) = 0.9.

**Solving the Model**

It is now possible to solve the model by applying procedures listed briefly at the beginning of section II:

- Provide all required input data. Most if not all models include equations expressing relationships among variables which are lagged with respect to time. For example, consumption this quarter may be specified as depending on income, not only in the current quarter as in the small model developed here, but also in one or more previous quarters. If lagged variables appear in equations of the model, then their numerical values must be provided.
before the model can be solved for future values of the endogenous variables.

- Provide all necessary input assumptions. For the most part this involves determining values the exogenous variables will take on in each of the future quarters to be forecasted. The simple model developed here has three exogenous variables: the tax rate (t), government spending (G) and the interest rate (r).

- Provide suitable mathematical methods to compute numerical values of endogenous variables from the equations of the model. In large models this can be a difficult task requiring complicated mathematical approximation procedures and large computers to perform the thousands of arithmetic operations required. Difficulties arise partly because the equations are interacting so that no single equation can be solved by itself. For some kinds of these "simultaneous equation" problems, exact mathematical procedures are known to directly solve the equations. For more complicated kinds of equations — the type used in most econometric models — exact solution procedures are not known. It then becomes necessary to use the computer in a systematic trial and error search for solution values of the endogenous variables. Figure 6 characterizes the steps necessary to solve a model.

Before turning to large models, a simplified example using the small model in monetary policy decision making will help tie together the material discussed so far.

Figure 6. Steps in Solving a Model

INPUTS...

- Historical input data
- Predetermined estimates of future values of the exogenous variables

THE MODEL...

- System of Equations (one equation for each endogenous variable)

SOLUTION...

- Predicted future values for all endogenous variables
Using the Model for Policy Making

Suppose the Federal Reserve System as central monetary authority is deliberating monetary policy for the coming quarter. Recall that the monetary policy instrument variable is the interest rate (\(r\%\)). Suppose current policy has the rate set at 4\%, and to simplify the problem further, the only alternative under consideration is a proposed increase in the rate to 8\%. In order to make a rational choice, monetary policy makers must know the implications of each alternative policy for the goal variables (gross national product, employment, prices and so on). Forecasting models are used to provide a connecting link between the instrument variables — those under direct or semidirect control of the policy makers — and the goal variables — those which policy is ultimately intended to influence.

To apply the simple model, estimates of future values of each of the three exogenous variables must be provided. One of these, the interest rate, has been discussed. It was agreed that the interest rate will be set at either 4\% or 8\%. Two additional exogenous variables remain: government spending (\(G\)) and the tax rate (\(t\%\)).

Suppose the published federal budget specifies government expenditures next quarter of $95 billion. Then \(G = 95\) billion. Assume the current tax rate is 12\% but that legislation is under consideration which, if adopted, would lower the rate to 10\%. The simple model can easily be solved for all four possible combinations of tax rates and interest rates. Forecasted values of the goal variables can then be examined to determine which choice of the instrument variable (the interest rate) is expected to come closest to achieving policy goals.

Figure 1 shows some data the simple model can provide. If both the tax rate and interest rate remain unchanged (12\% and 4\% respectively) then income (\(Y\)) is predicted to be $906 billion. If the Federal Reserve pushes the interest rate to 8\% while the tax rate stays at 12\%, forecasted income is $23 billion less at $883 billion. Other questions can be asked about forecasted values of income and other variables under alternative policies. More generally, the forecast values can be used along with a particular strategy thought by the policy maker to be effective in maximizing the chance of achieving the goals. For example, current monetary and fiscal policy \((r = 4\%, t = 12\%)\) imply an expected income level of $906 billion. Suppose Federal Reserve policy makers believe a somewhat more expansionary overall economic policy is needed, one which will stimulate the economy to an expected income level of $976 billion. They may then choose to support proposed legislation to reduce the tax rate to 10\% and simultaneously plan to raise the interest rate to 8\%, partially offsetting the fiscal stimulus. But commitment to a particular monetary policy may have to be made before it is known what the Congress will decide on taxes. How should the Fed decide its policy?

One strategy the Fed could choose to employ — called a minimax* strategy — says choose the policy alternative for which the worst possible outcome is least bad. Assume the Fed feels a proper measure of “bad” (loss) in this case is simply the dollar amount by which income deviates, whether on the high side or low side, from

*The shorthand label for a strategy which “minimizes the maximum loss.”
tax rate will be reduced, then a correspondingly strong case can be made for increasing interest rates to 8% in the hope of exactly achieving the target level of income ($976 billion) thereby incurring zero loss.

The mathematics of these and similar strategies is well developed in principle but frequently difficult to apply in practice. In addition, new, more complex strategies are being studied by economists; strategies which ask if, and in what ways, the various agents that make up the economy may determine their behavior in part on what they expect economic policy to be. If business firms and consumers expect economic policy to be set in a certain way, this expectation itself may play an important role in determining their decisions and hence the actual economic outcome.

This illustrates some of the ways models can be used by policy makers. The simple model developed here is clearly inadequate in many respects. As noted earlier, it lacks a labor sector and price equations and so reveals nothing about the effects of policy on future employment and inflation. To sum it up, this model is simple so it was easy to construct. It was easy to estimate and easy to solve. A price of simplicity is lack of information that can be provided for policy making. Section III describes large scale models and how they are used.

the target income level of $976 billion. Figure 8 shows the amount of “miss” for each combination of interest rate and tax rate. If the Fed stays at a 4% interest rate setting, the worst outcome that can occur is a miss of $70 billion (low), which would result if Congress keeps the tax rate at 12%. The worst outcome possible if the interest rate is set at 8% is a miss of $93 billion (again low). The minimax strategy hence would tell the Fed to keep the interest rate at 4%, even though this choice restricts the best possible outcome to a loss of $25 billion (high) which would occur at t = 10%.

Minimax is a very conservative strategy, giving heavy weight to the worst possible outcomes regardless of how likely or unlikely their occurrence may be. Other strategies exist which make use of information on the likelihood that Congress will pass the legislation. This is intuitively reasonable. If the Fed believes it is very likely that the
Large Scale Models and Economic Policy Making

This section will review the nature, application and accuracy of econometric forecasting models actually in use by examining

- the size and complexity of econometric forecasting models,
- the role of these models in monetary policy making, and
- the forecasting accuracy of the models.

Size and Complexity

Econometric forecasting models tend to have a large number of equations, and the number tends to grow over time. The current Wharton model,* for instance, has over two hundred equations and requires specification of future values for nearly 80 exogenous variables. This version of the model has more than double the number of equations of its immediate predecessor. Another example, the MPS model,** was reported in 1968 to have roughly 100 equations; the current version has close to 200 equations. Before considering this trend to larger models, it is useful to elaborate on the earlier definition of a model.

Models of the economy must necessarily group quite diverse events in a few, broad categories. In the simple model of the previous section, all types of expenditures are grouped into three mutually exclusive categories: “consumption,” “investment” and “government purchases.” In economic parlance these broad categories are referred to as aggregates. Whether a household purchases a stalk of celery, an automobile or a television repair service, the event is considered “consumption” in the simple model. A model having more aggregates might distinguish between “consumption of edulcorable goods” (celery), “consumption of durable goods” (automobile) and “consumption of services” (TV repair work).

*A model of the economy then is more than a collection of equations; it is a collection of behavioral relations and identities which describe the demand, supply and price of aggregate economic variables. The behavioral relations and the identities are expressed as equations, and there must be as many equations as there are endogenous aggregate variables. A solution to the model is a set of numerical values for the endogenous variables which satisfy each equation in the model.

Increasing the number of aggregates in a model enables finer distinctions among various economic events. The process of dividing larger economic aggregates into smaller ones is termed disaggregation. As a model becomes more disaggregated, the number of equations increases. Probably the single most important factor behind the trend to larger and larger models has been a trend to greater and greater disaggregation.

What are some of the advantages of disaggregation? An important one is that the more disaggregated a model is, the more information it can provide. Economists and economic policy makers have much interest in what is going to happen to prices, unemployment, real output, the balance of payments, housing construction and numerous other things. The simple model gave no information on these items because it was not sufficiently disaggregated.

There are other advantages to disaggregation, some of which become apparent by examining the investment sector of the Wharton model. While the simple model has one aggregate for investment, the Wharton model has nine. This means that the Wharton model distinguishes between nine types of investment: six are determined by the model and the other three (types of farm investment) are specified exogenously. A first stage of disaggregation is a division of investment between inventory investment and fixed investment (see Figure 9a). Intuitively, this seems reasonable. A decision to invest in inventories is made for different reasons and based on different considerations from a decision to invest in plant and equipment. In addition, it is not just...
the total amount of investment that matters for forecasting; the composition of investment between inventories and fixed investment also has implications for future production. High inventory investment and low fixed investment in a current quarter might portend a production slowdown in future quarters if firms attempt to deplete inventories until more desirable levels are reached. On the other hand, relatively low inventory investment and high fixed investment in a current quarter might presage a business expansion. In this case producers might be expected to increase output not only to satisfy sales needs but also to rebuild inventories.

A second stage of disaggregation of investment in the Wharton model is a breakdown along industry lines (see Figure 9b). This second stage points to two additional reasons for disaggregation. First, it is easier and more straightforward to incorporate new information into the model.
Hence, when new depreciation guidelines were announced by the government in 1971, Wharton economists needed only to determine the direct effect of the guidelines on plant and equipment investment in manufacturing and regulated industries to update their model. Second, disaggregation can facilitate efforts to discover weaknesses in the model’s structure. In 1970 Wharton economists found that the equation for plant and equipment investment in regulated industries was doing a poor job of predicting. Because they were dealing with a disaggregated model, they were able to discover the source of the problem quickly and were able to make the necessary adjustments.

Thus, a disaggregated model offers certain advantages:
- more economic variables can be predicted;
- the model’s predictions can be improved when the composition of an aggregate has important implications for forecasting;
- new information can be incorporated more easily into the model; and
- weaknesses in the model’s structure can be discovered — and corrections made — more easily.

However, along with these advantages go some costs. As a model gets larger, difficulties do not just add up, they multiply. Data maintenance becomes a major undertaking requiring a sizable staff. New data must be transformed to a usable, accessible form and kept up to date. The MPS model, for instance, makes use of more than 300 statistical series which must be processed and updated almost continually.

Difficulties in estimating models, programming them for computers and solving them also tend to multiply with further disaggregation. Adding equations increases the complexity of a model’s structure, making it difficult to work with and even more difficult to understand. As each new variable is introduced, the linkage between it and other variables in the model must be determined so that a unified interacting system results. The size and complexity of today’s large models make the use of high speed, high capacity, scientific computers an absolute necessity.

Comparison of the simple model and the Wharton model provides a dramatic example of the increase in complexity which disaggregation can cause. The economic structures of these two models can be given pictorial representations, commonly referred to as flow charts (see Figure 10). A geometric figure in the flow chart denotes an economic variable, and a directed line from one variable to another indicates that the value of the first variable has a direct effect on the value of the second variable. In other words, the first variable appears in the equation used to solve for the second variable. In the simple model the flow chart shows, for example, that the value of the interest rate has a direct effect on the level of business investment which, in turn, is a determining factor of total income. The extreme simplicity of this model is evidenced by the paucity of geometric figures and lines in the flow chart.
The flow chart of the Wharton model, on the other hand, reveals a large, interacting structure (see Figure 11). The geometric figures have the same meaning as before, but the Wharton model flow chart has three types of directed lines to distinguish time lags. A heavy solid line indicates that one variable affects another with no lag, a dashed line indicates effect with a one quarter lag, while a narrow line indicates effect with a lag of longer than one quarter. The multitude of geometric figures and lines in this flow chart reflect the size and interactive nature of the Wharton model.

Not only do models as a whole grow more complex as the number of equations increases, but individual equations also become more complicated. Equations grow longer and often become more mathematically involved. A comparison of analogous equations in the simple model and the Wharton model is a contrast in complexity (see Figure 12). Total investment in the simple model depends only on the current value of the interest rate. In the Wharton model the "manufacturing investment in plant and equipment" component of total investment depends on five variables: the long-term interest rate, output in manufacturing, capacity utilization, stock of manufacturing investment and business saving. Notice that the current values of these variables do not even enter the equation; the variables enter with time lags of up to nine quarters. In particular, the value of the long-term interest rate nine quarters ago is shown to have an effect on investment today.
And alternatively, if the long-term interest rate changes in the current quarter, the Wharton equation indicates it will have an effect on investment nine quarters from now.

In summary, while disaggregation offers certain advantages, it also gives rise to certain costs. Some of these costs are:

- data maintenance becomes a major undertaking;
- the model becomes more difficult to understand because of greater complexity in the economic structure and individual equations; and
- the model becomes more difficult to estimate, program and solve.

Add to these costs the much greater likelihood of errors in construction and operation, and it is easy to see that a larger model is not necessarily a better model. The econometrician must weigh the advantages of disaggregating the model further against the costs. Increased technical know-how and advances in the computer field have in the past tempered the costs and tipped the scales in favor of further disaggregation. It would not be surprising to see this trend come to a halt.

The Role of Models in Monetary Policy Making

The broad economic goals of government policy, as officially stated in the Employment Act of 1946, are “. . . to promote maximum employment, production, and purchasing power.” The monetary policy maker does not influence employment, production or prices directly. The things he does control, called policy instrument variables, are member bank reserve requirements, the discount rate, the Fed’s portfolio of securities and Regulation Q (which governs maximum rates of interest payable on time, savings and demand deposits). The role of econometric forecasting models in monetary policy making is to provide the policy maker with a link between values of instrument variables and economic outcomes in terms of policy goals. Models accomplish this by generating forecasts which are conditional on policy choice (specified values of instrument variables). Although different techniques can be employed to make an economic forecast, econometric models are the only practical means of generating forecasts under alternative policy assumptions. Other techniques are either too cumbersome or too limited to provide alternative forecasts conditional on policy choices.

For each policy alternative policy makers consider, they must try to answer the question: “What would happen to prices, unemployment and output if this policy were implemented?” It would be naive to suggest that models can provide precise, uncontestable answers to questions of this type. However, they do provide systematic and consistent answers which can serve usefully as guides.

Different monetary policies are commonly indexed by the annual growth rate in the stock of money (currency plus private demand deposits) which they imply. Thus, a 7 percent annual growth rate in the money stock implies a more stimulative policy (and a more liberal setting of policy instrument variables) than does a 6 percent rate. In the middle of 1970 the Research Department at this Bank used a modified version of the Wharton model to examine the forecasted economic impact of alternative monetary policies. Some of the findings of that experiment are graphed in Figures 13, 14 and 15. Note that the outcomes are paths of variables over time. In the case of unemployment, for example, the model predicts how the unemployment rate will respond quarter by quarter under different monetary policies. This is important because the policy maker needs to know not only what unemployment will be at some future time but also whether it is declining, steady or rising.

Based on this experiment, policy makers could examine the predicted implications of alternative policies and then choose the one which provided the “best” outcome. They might be hesitant, however, to choose policy solely on the basis of the experimental findings. For one thing, they might not trust the model fully, especially when its implications run contrary to intuition or economic
theory. The main finding of this experiment was that implementing a more expansionary policy than the then current 5 percent growth rate in the money stock would lead to significantly more output and less unemployment while having little effect on prices. However, the outcome for prices as graphed in Figure 15 appears suspect. A 20 percent growth rate in the money stock was predicted to have little more inflationary impact than a 3 percent growth rate. The graph also indicates that under any of the policies the rate of inflation would be negative in the first quarter of 1972. These highly suspect results raise the question of the forecasting accuracy of models, a topic taken up in the next section.

Even if policy makers trusted the model, they might be wary of choosing a policy such as the 20 percent money stock growth rate. Such a policy is very different from the historical norm, and the degree of uncertainty surrounding its predicted outcome is probably very great. This uncertainty can be measured. Econometric models can be used to generate a range (or “distribution”) of outcomes for each setting of policy variables. Thus, the models can tell us not only the most likely outcome associated with each policy, but also something about the likely range of outcomes. Using a model in this way, a forecast might be stated: “if growth in the money stock proceeds at a 5 percent rate in the current year, GNP for the year will most likely be $1,100 billion, and with 90 percent certainty it will be between $1,080 billion and $1,120 billion.” Because policy makers prefer more certainty to less and because the uncertainty of outcomes differs with different policies, this use of the model can provide additional helpful information.

Policy makers might still object that if their decision were based solely on these experimental findings, the policy choice would be limited by the alternatives specified. They might wonder about other policies, such as “a 5 percent growth rate in the money stock in the current quarter and a 7 percent rate next quarter and beyond.” They might even have a more sophisticated strategy in mind such as “keep policy at its current setting this quarter, ease up next quarter if the actual outcome is worse than predicted.” The objection is valid, but it can be overcome by carrying out this policy experiment in a more effective manner. This new method begins by having the policy makers state preferences among alternative economic outcomes. The model can then be solved for the policy which best suits their preferences. In effect solving the model in this way can be thought of as a search over an infinite number of policies to find one which implies the “best” outcome. In the simple experiment a policy is specified, and the model is solved to obtain the economic outcome; according to this new method a desired outcome is specified, and the model is solved to obtain the “best” policy — a complete reversal of operations.

No matter how a model is used, its essential role in policy making is to provide a link between policy actions and economic consequences. Sophisticated use of a model permits measures of outcome uncertainties to be associated with different policy actions, and it permits the policy maker to make a decision from a virtually unlimited set of alternatives.

The Forecasting Accuracy of Econometric Models

The question of how well econometric models forecast is not easy to answer. Much work has been done on this, but little of it is very scientific. Since a definite answer to this question of forecasting accuracy cannot be given, the present discussion centers on some of the problems and issues involved.

The term “accuracy” must be carefully defined when applied to econometric models. Models predict the values of many variables over quite a few quarters into the future. It may happen that a model predicts some variables accurately and others not so well. A common impression of econometric models is that they do reasonably well on real output but poorly on prices. Even for variables which a model does predict well, it is likely that accuracy diminishes as predictions go
Further into the future. So rather than asking a question as general as "How accurate is the model?", it is necessary to ask a more specific question such as "How accurately does the model forecast GNP two quarters hence?" However, specific questions also raise issues which are not easily resolved.

Measuring the accuracy of economic forecasts is complicated by the existence of sizable errors in the actual, reported data. Because a forecasting error is defined as the difference between a predicted value and the actual outcome, part of a measured forecasting error may not be a forecasting error at all; it may be solely the result of erroneous statistical data (see Figure 16).

Faulty economic data can cause a model's input to be in error, and a forecast based on erroneous information cannot be expected to be accurate. However, there are errors in econometric forecasts which would remain even if the input were accurate. They stem from misspecification of exogenous variables and deficiencies in the estimated structures of models.

In order to solve an econometric model, values must be specified for exogenous variables over future quarters. These specified values are in reality projections formulated outside the model. Errors naturally occur in forecasts of endogenous variables when predictions of exogenous variables are incorrect.

Figure 16. Forecasted vs. Actual GNP for 1967:1Q

<table>
<thead>
<tr>
<th></th>
<th>$ billion</th>
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<tbody>
<tr>
<td>Wharton Forecast</td>
<td>771.3</td>
</tr>
<tr>
<td>of GNP for 1967:1Q</td>
<td></td>
</tr>
<tr>
<td>(made December, 1966)</td>
<td></td>
</tr>
<tr>
<td>April 1967 Issue</td>
<td>764.3</td>
</tr>
<tr>
<td>May 1967 Issue</td>
<td>763.7</td>
</tr>
<tr>
<td>July 1967 Issue</td>
<td>766.3</td>
</tr>
<tr>
<td>July 1968 Issue</td>
<td>772.3</td>
</tr>
<tr>
<td>July 1969 Issue</td>
<td>774.2</td>
</tr>
</tbody>
</table>

Actual GNP for 1967:1Q, reported in selected issues of Survey of Current Business
Errors in predicting exogenous variables are made for a variety of reasons. A prediction may have been unsound from the outset or some extraordinary event may have occurred to throw it off the mark. Predictions of government policy variables are sometimes in error because of faulty policy projections contained in public documents. In fiscal 1967, as an extreme case, defense expenditures were underestimated in the federal budget by $10 billion. A faulty projection of this magnitude is certain to cause gross errors in forecasts of the National Income Accounts.

Errors due to deficiencies in estimated structures are present in all econometric models because all models are only very crude approximations of reality. A measure of a model's crudeness is the size of outcome ranges it implies. For example, one model might indicate that, with 90 percent certainty, annual GNP can be expected to fall in a $20 billion range. A cruder model might indicate a $40 billion range. Over the long haul, forecast errors of the first model can be expected to be smaller than those of the cruder model. However, even after allowing for a model's crudeness, it may be deficient in the sense that the ranges it implies for given levels of uncertainty no longer describe the actual economy. For instance, suppose actual GNP over 10 years is compared with the outcomes predicted by the first model. It would be expected that in about 9 out of the 10 years (90 percent of the time corresponds to 90 percent certainty) actual GNP would fall within the $20 billion range predicted by the model. If, in fact, actual GNP fell inside the range only two out of the ten years, it would probably be concluded that the model no longer provided an accurate description of the actual economy. Statistical tests exist to determine whether a model, or parts of a model, suffer this type of deficiency. Most econometric models subjected to these tests have not fared very well.

From the evidence economists have assembled thus far, it appears that econometric models do not forecast well. However, there is another consideration, one which may be the most important of all. Econometric forecasting as it exists today is more an art than a science. It requires close interaction between the econometricians and their models. Models provide econometricians with a method of issuing consistent forecasts from systematically organized historical data. Econometricians must supply judgment and newly acquired information to augment the structures of the models. Learning, for example, that a steel strike of six weeks is a likely event in the months ahead, they must determine how to adapt the models to account for this new information. In some cases econometricians may alter their models in an attempt to correct persistent errors, or simply because some aspects of the forecasts seem unreasonable. Although models by themselves do not forecast well, skilled econometricians supplying their judgment to the formal structures of models have been quite successful. Econometric models are still in an early stage of development, but they are already an important, useful tool in economic forecasting and policy making.