Forecasting the Economy with Mathematical Models: Is It Worth the Effort?

By Nariman Behravesh

The months following the Arab oil embargo of 1973–74 could well go down in history as the nadir of the art and science of economic forecasting. The embargo, oil price increases, and the ensuing recession jarred the U. S. economy, leaving economists with forecasts that were in many cases embarrassingly wrong. For example, errors associated with price level and real GNP predictions as much as tripled after mid-1973.[1] Quite a comedown for those who in earlier years had earned high marks for forecasting!

On average, forecasters who keyed their predictions only to mathematical or econometric models were proved less accurate than those who relied on pure judgment or a combination of judgment and econometrics.[2] The quality of the forecasters' judgment helped to determine the relative accuracy of economic predictions during this period. Less clear-cut, though, is the degree to which econometric models helped or hindered those who used them.

Some skepticism about econometric forecasting is clearly justified. Mathematical models are still in their formative stages. When used to forecast the economy, they tend to underestimate the peaks (high points) and troughs (low points) in business cycles and to miss the timing of these business cycle turns. Yet, most forecasters using econometric models can compensate for

[1]See Stephen K. McNees, "How Accurate Are Economic Forecasts?" *New England Economic Review* of the Federal Reserve Bank of Boston, November/December 1974, pp. 2–19.

[2]Ibid. A judgmental forecast is formulated without the help of an econometric model but depends on a variety of inputs including the forecaster's intuition, trend projections, and the use of leading indicators.

weaknesses inherent in the models. These models are invaluable for zeroing in on the effects of policy changes on the economy. Moreover, since considerable research in empirical economics is being directed at refining these models, forecasters will probably find them increasingly useful aids for prognostication.

INSIDE A PANDORA'S BOX

An econometric model used by a forecaster is a set of mathematical and statistical relationships that purports to describe economic behavior. These models are based on economic theory and, in the process of model-building, the relationships in the models are estimated and tested using the historical data (see Box).

Most econometric models used in predicting the status of the economy are quite large (40 to 400 equations). These so-called macroeconometric models are designed to predict economic variables such as the Gross National Product, the price level, the unemployment rate, and interest rates. Such variables, which are determined within the model, can be called *internal variables*. To a large extent, these internal variables may influence each other. For example, GNP is directly related to national income, which influences consumers' expenditures on goods and services, which in turn helps to determine GNP. However, these internal variables also depend on other variables such as Government expenditures, exports, tax rates, and lending rates of central banks—some of which may not be determined purely by economic forces. These variables can be called *external variables* because they are not explicitly determined by the model.[3] A forecaster intending to use a model to predict economic activity must supply the predicted values for these external variables.

[3]Determination of whether a variable is internal or external to the model depends on its builder. For example, some model builders may designate Government expenditures as an external variable since these expenditures are determined by a number of noneconomic forces that the model cannot consider. Other model builders may feel that Government spending depends primarily on economic activity and, therefore, should be included among the internal variables and described explicitly by the model. Econometric models must always have some external variables; otherwise, the forecaster faces an everything-depends-on-everything-else situation.

ANATOMY OF AN ECONOMETRIC FORECAST

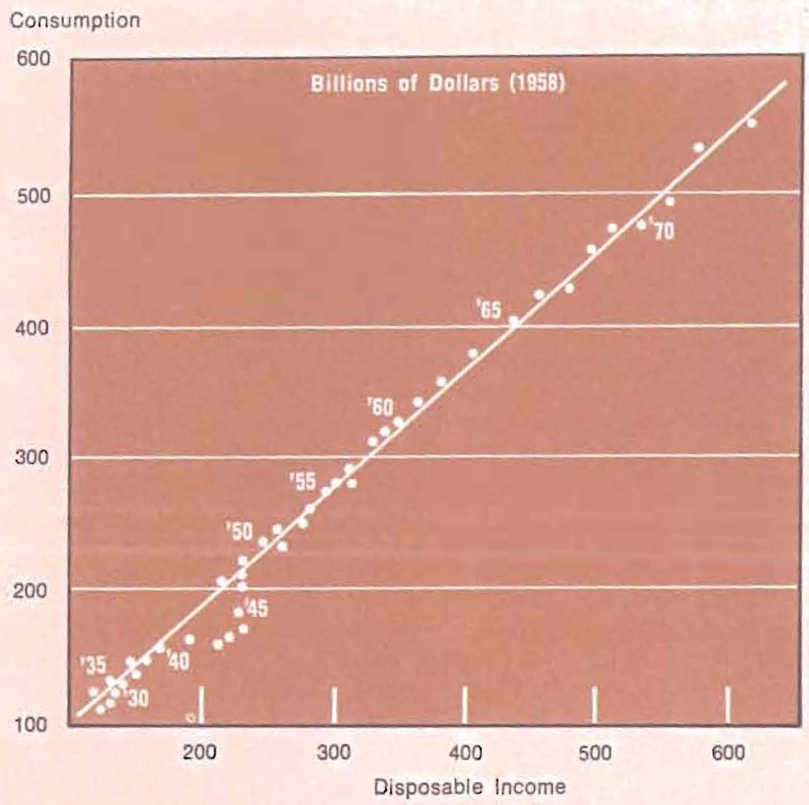
Building a Model. If we were interested in building an econometric model our immediate questions would be: What economic variables do we want to describe? What does economic theory have to say about these variables? What does the data show about these variables? Here is how these questions may be answered.

Suppose, for example, we want an overall description of consumption behavior in the U. S. economy. A review of relevant economic theories might turn up this assertion: Aggregate consumption is related to disposable or after-tax income. If the data for consumption and disposable income were graphed (see Diagram), the scatter of points would lie nearly on a straight line with a slope of about nine-tenths. Then it could be said that on average in the U. S., nine-tenths of disposable income is used for consumption expenditures.* In mathematical terms, this relationship would be:

$$\text{Consumption} = .9 \times \text{Disposable income.}$$

*The consumption relationship being described is a long-term one. The distinction between long- and short-term consumption will not be made in the interests of simplicity.

RELATIONSHIP BETWEEN CONSUMPTION AND DISPOSABLE INCOME.



Notice that this simple relationship is not an exact one. For example, in the Depression and war years, consumption was less than nine-tenths of disposable income (that is, in the Diagram, the observations for these years fall below the line). The opposite is true for the '60s. The inexactness of this simple model can be traced to factors such as changes in wealth, depressions, and wars that have not been taken into account. The model builder can rewrite the consumption equation to account for the approximate nature of the model:

$$\text{Consumption} = .9 \times \text{Disposable income} + \text{Error}$$

"Error" refers to all the factors that affect consumption which the model builder has not taken into account. By including some of these factors in the consumption equation, the size of the error can be reduced.** If this consumption model were used for forecasting,

**If more han one explanatory variable is used to describe consumption, plotting the data and fitting a line as we have done in Chart 2 would be difficult. However, there are statistical methods that can do the same thing.

the reduction of this error would be a step toward more accurate forecasts.

Another salient characteristic about the scatter of points in Chart 2 is that if consumption is below average (that is, below the line) in a particular year, then it is likely that it will be below average for a few years (the war years). The same is true when consumption is above average (the '60s). This tells us that consumption patterns vary slowly in response to changes in the economy—that is, the "error" or unexplained portion of the consumption model is not random. In fact, this error is systematic and correlated with its past and future values (econometricians refer to this type of error as serially correlated). Systematic or serially correlated errors are common in macroeconometric models and should be taken into account when these models are used for forecasting.

Forecasting with a Model. An econometric forecast is obtained by projecting the estimated model to include the year or years of interest. Suppose we were interested in predicting consumption expenditures in the United States in 1974 and 1975. If it were known that disposable income in those years was $650 billion and $750 billion (measured in 1958 dollars), respectively, then the simple model introduced above could be used to forecast consumption. This model would predict consumption in 1974 and 1975 to be $580 billion and $630 billion, respectively (also measured in 1958 dollars).

Such forecasts are approximate, since by ignoring the other factors that affect consumption in the simple model, these factors are ignored when this model is used to predict consumption. Sharp-eyed forecasters would have to decide if there were any factors that would induce more or less consumption in 1974 or 1975. For example, if it were expected that economic activity was slower than usual in these years, then consumption would also be subpar; therefore, we would want to adjust the predicted consumption levels downward. In this way we would be able to consider the "other factors" which affect consumption and which the simple model does not take into account. A more sophisticated forecaster would weigh the possibility that if consumption fell below average in any one year it may remain there in the following years (that is, economic variables may move slowly through time). To compensate, we would adjust consumption downward for a greater time. Thus, an econometric model tempered by the forecaster's judgment can yield better forecasts.

Multiequation Models. The model presented above has a number of shortcomings. From a behavioral point of view, it is a simplistic model of consumption. From a forecasting point of view, this single-equation model depends on forecasts of disposable income, which may be just as difficult to predict as consumption expenditure. Furthermore, disposable income is influenced by the level of consumption in the economy (since consumption contributes to GNP, which is directly related to disposable income). These types of problems are usually solved by adding more equations to the model.

Just as consumption forecasts required us to supply predictions of disposable income in the above model, forecasts of the internal variables of a large econometric model (such as GNP, prices, and unemployment) require predictions of the external variables (such as Government expenditures, taxes, and the money supply). Furthermore, in the same way that the consumption forecasts above could be modified to account for information not already included in the models, adjustments can be made to the forecasts of large econometric models.

THE CYCLES PRODUCED BY AN ECONOMETRIC MODEL

The value and reliability of macroeconometric models in forecasting business cycles can be studied in two ways. The first method compares the actual historical *values* of key internal variables such as real GNP with the values a forecaster would have obtained from the model. This method provides insight into the model's ability to duplicate the economic conditions which occurred, when it is supplied with the actual historical values of the external variables. The second method compares the size and duration of *fluctuations* for a predicted variable, such as real GNP, with the actual business cycle fluctuations of that variable. Such a comparison would allow the forecaster to judge the reasonableness of the business cycles produced by the model when he has to rely on forecasts of the external variables. The model under scrutiny here represents the state of econometric model-building in the late 1960s.

Chart 1 compares the actual values of real GNP from 1956 to 1965 with a historical forecast of real GNP by an econometric model.[4] The predicted values rise and fall at about the right time but don't trace out the cycles in real GNP very well. In fact, these forecast values underestimate both the peaks and the troughs in the actual series. One explanation for this difference may be that the peaks and the troughs in the actual series were caused by unanticipated occurrences that the model was not "smart" enough to capture. These unanticipated events or "shocks" may have consisted of major strikes, changes in international markets, or shifts in Government policies that were not explicitly built into the model.

The second method of analyzing the "tracking" record of an econometric model —looking at the long-run forecasts it generates—yields similar conclusions. Forecasters wishing to make long-run predictions must begin by predicting the long-run changes in the external variables.[5] As a result, these long-term forecasts are no more accurate than the predictions of the external variables supplied by the forecaster. For lack of better information, long-run forecasters usually assume that external variables will change slowly and with virtually no fluctuations. However, this implies that the long-run forecasts generated by an econometric model may also be fluctuation-free (Chart 2—dashed line). Clearly, such forecasts do not trace out anything resembling a business cycle.

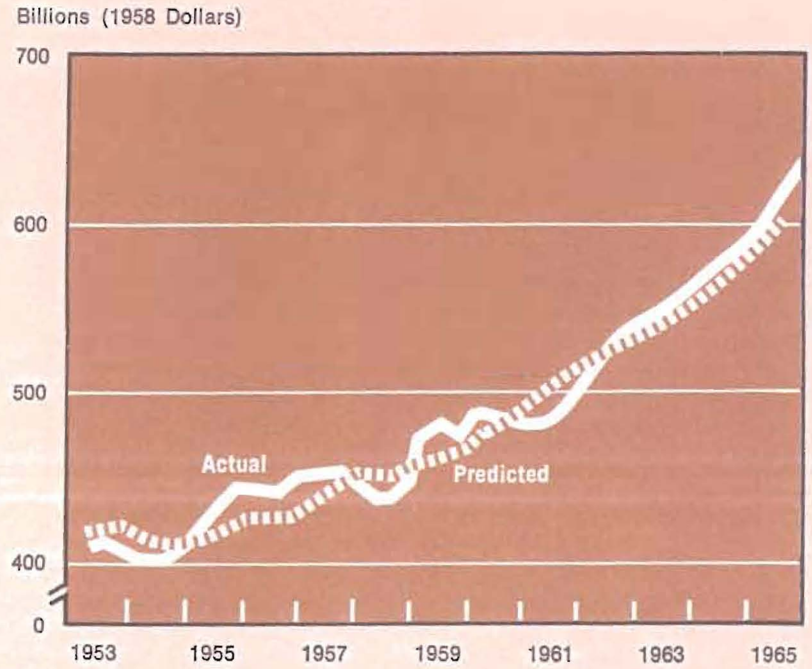
More realistic cycles can be traced by econometric models if the modeler tries to account for the occurrence and impact on the economy of events such as wars, strikes, and embargoes. One way of doing this is to impose random shocks on the models (Chart 2—dotted line). But these cycles are too frequent and short-lived compared to an actual series such as in Chart 1. These cycles are too short because the model moves the economy back to a "normal" position immediately after the shock is felt. However, in reality, the economy often takes more time to adjust to such disruptions. If the model user spreads the impact of these shocks over a number of

[4]Historical, or after-the-fact, forecasts used in the first method of analyzing the tracking record of econometric models require that the user provide values of the external variables of the models (such as Government expenditures, taxes, and exports). In these forecasts the external variables are set at their actual historical values. Data for these external variables are fed into an econometric model which then predicts the values of internal variables such as real GNP, prices, and unemployment.

[5]Unfortunately, usable forecasts of the external variables may be as difficult to get as predictions of the internal variables. Short-term forecasts of variables such as Government spending, taxes, and money supply growth may be easily obtained through Government budget estimates and other sources. However, getting accurate long-run forecasts of such external variables is a tougher undertaking. This, in turn, undermines the accuracy of all long-term forecasts, both econometric and judgmental.

CHART 1

MODELS TEND TO UNDERESTIMATE THE ACTUAL PEAKS AND TROUGHS OF A BUSINESS CYCLE.



SOURCE: B. G. Hickman, ed., *Econometric Models of Cyclical Behavior* (New York: National Bureau of Economic Research, 1972).

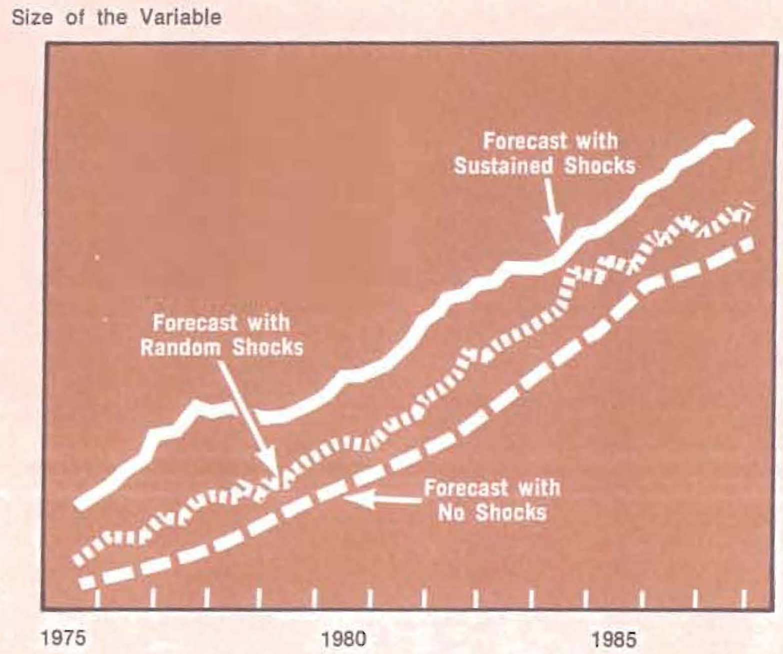
periods, the fluctuations in the predicted series are smoother and begin to resemble the actual fluctuations in the series. (Compare the solid line in Chart 2 with the actual series in Chart 1.)

Accordingly, model users must be wary of the fact that business cycles produced by econometric forecasts are less pronounced than those the economy normally experiences.[6] In part, this may be a result of the inability of the models to foresee and, therefore, cope with the impact of unanticipated events, especially those whose impacts are spread over a number of periods. Fortunately, judicious use of judgmental information can at least partially compensate for such model weaknesses.

[6]The smoothness of econometric forecasts relative to economic time series may be explained in two different ways. On the one hand, econometric models may not be good representations of economic structure and, therefore, cannot duplicate business cycle behavior. On the other hand, econometric models may be good representations of the economy if, indeed, business cycles are a result of shocks to an economy which would otherwise be stable. It can then be argued that no matter how good a model is, it will inevitably fail to predict some unanticipated shocks and, consequently, miss some business cycle fluctuations.

CHART 2

LONG-RUN FORECASTS OF REAL GNP WITH AND WITHOUT SHOCKS.



SOURCE: B. G. Hickman, ed., *Econometric Models of Cyclical Behavior* (New York: National Bureau of Economic Research, 1972).

THE TRACKING PERFORMANCE OF SOME MODELS

How accurately have forecasters relying solely on some of the major econometric models been able to spot the timing and magnitude of business cycle turns?[7] A look at the 1969 versions of three models which make quarterly forecasts provides some clues as to their ability to track past business cycles.[8] Although these models have changed significantly since 1969, the state of the art has probably not changed enough to make the types of results presented here obsolete.

[7]A turning point in the business cycle occurs when the economy shifts from a positive growth period to a negative growth period and vice versa. The former points are called peaks and the latter troughs in the reference-cycle terminology of the National Bureau of Economic Research.

[8]Victor Zarnowitz, Charlotte Boschan, and Geoffrey H. Moore, "Business Cycle Analysis of Econometric Model Simulation," in B. G. Hickman, ed., *Econometric Models of Cyclical Behavior* (New York: National Bureau of Economic Research, 1972), pp. 311–541. The models considered in this study are the Wharton Econometric Forecasting Unit model, the Office of Business Economics model, and the MIT-Penn-Fed model.

Spotting the Turning Points. Table 1 summarizes the accuracy with which these three models were able to predict the timing of turning points for six-quarter historical forecasts.[9] On average the historical forecasts spotted a turning point two-thirds of the time when the economy actually peaked or bottomed out. There did not seem to be a tendency on the part of the models to predict a turning point when one did not occur.

The models tended to predict turns too soon. This is especially true for historical forecasts that preceded the turning point by three quarters. The closer the turning point to the start of the forecast period, the better the chance of calling the turn. These results did not differ for upturns or downturns.

In order to correct such errors, it would help if the forecaster could pinpoint some of their sources. The forecasting mechanism of business cycles in many quarterly models is linked to investment and inventory cycles, both of which are leading indicators in business cycles.[10] However, investment and inventory cycles are not the only factors that account for business cycles in the economy. It is entirely possible that model builders haven't fully accounted for the complex linkages between such leading indicators and the economy. Generally, the closer the turning point, the more useful and reliable the information that signals the turn will be to the model. So, the closer the forecast is to the turning point the greater is the likelihood that the model will correctly spot the cycle peaks and troughs. In general, a

[9]A six-quarter historical forecast starting, for example, three quarters ahead of the turning point, would begin nine months before the quarter in which the turn occurred and would end six months after the quarter of the turn. It should be remembered that for a historical forecast the external variables are set to their actual historical values.

[10]Leading indicators are economic variables that will usually peak before the economy peaks and bottom out before the end of a recession. These indicators are identified and classified by the National Bureau of Economic Research.

TABLE 1

HOW THREE MODELS* SPOTTED TURNING POINTS: 1957–61**

	Too Soon	Too Late	On Time
Average of Forecasts Starting 3 Quarters Ahead of Turning Point	43%	26%	31%
Average of Forecasts Starting 2 Quarters Ahead of Turning Point	37	28	35
Average of Forecasts Starting 1 Quarter Ahead of Turning Point	28	33	39
Average of All Forecasts	36	29	35

*The three models in question are the 1969 versions of the Wharton, Bureau of Economic Analysis, and MIT-Penn-Fed models.

**Victor Zarnowitz, Charlotte Boschan, and Geoffrey H. Moore, "Business Cycle Analysis of Econometric Model Simulations," in B. G. Hickman, ed., *Econometric Models of Cyclical Behavior* (New York: National Bureau of Economic Research, 1972), pp. 311–541.

TABLE 2

HOW THREE MODELS* FARED IN PREDICTING THE SIZE OF PEAKS AND TROUGHS: 1957–61**

	Too Large	Too Small	Correct
Average of Forecasts Starting 3 Quarters Ahead of Turning Point	21%	54%	25%
Average of Forecasts Starting 2 Quarters Ahead of Turning Point	15	62	23
Average of Forecasts Starting 1 Quarter Ahead of Turning Point	15	55	30
Average of All Forecasts	17	57	26
Average of Forecasts during Contractions	14	57	29
Average of Forecasts during Expansions	21	56	23

*The three models in question are the 1969 versions of the Wharton, Bureau of Economic Analysis, and MIT-Penn-Fed models.

**Zarnowitz, Boschan, and Moore, "Business Cycle Analysis of Econometric Model Simulations," in Hickman, ed., op. cit., pp. 311–541.

modeler must assume that short-run forecasts are more accurate than longer-run ones.

Predicting the Size of Peaks and Troughs. The Achilles heel of many macroeconometric models is their proclivity to smooth out business cycles and, in so doing, undershoot the size of both peaks and troughs. The three models under consideration did, in fact, smooth over past cycles (see Table 2). These models tended to underestimate both peaks and troughs. The closer the beginning of the forecast was to the actual turn, the better the chance the models had of correctly predicting the size of a peak or trough. On average, the models were better at foretelling the depth of the slide during a recession than they were at gauging the peak to which the economy rose before experiencing a contraction.

Models undershoot the size of the peaks and troughs for several reasons. In part, this may be a result of the model's tendency to predict a turning point too soon. If the models called a peak or a trough too early, then at the peak or trough the predicted series would underestimate the actual rise or decline that occurred. Undershoots can also result because the models ignore the cumulative effect of the "other factors" that are overlooked in the model structure. Here again, the closer the starting point of the forecast to the actual turning point, the better and more plentiful the information signaling the turn, and so the more accurate the forecasts.

SHARPENING THE FORECASTS

On the whole, this evidence suggests that, without adjustments by the forecaster, the tracking record of econometric models leaves some room for improvement. There are two general ways to hone the tracking and predictive abilities of econometric models. The first is numerically adjusting an existing model prediction to correct for past misses and to impose the forecaster's judgment. The second strategy is refining and improving the model itself.

Forecasters can improve their results by anticipating and mathematically correcting the tendencies of the models to smooth out economic fluctuations. This can be accomplished by looking at past error patterns (that is, the difference between the actual and the predicted series, such as in Chart 1), and adjusting the forecast to compensate for these errors. If, for example, a model tends to understate GNP growth during expansions and to overstate GNP growth during contractions, the model user can adjust GNP growth predicted by a model upward or downward to counteract this tendency. A great deal was learned about this process and about econometric models from the larger than usual forecasting errors made in the months right after the Arab oil embargo.

Most econometric forecasters will also use their judgment to anticipate the impact on the economy of events they expect to occur. This information is then used for the necessary adjustments to the forecast. For example, during the Arab oil embargo econometric forecasters tried to estimate the effect of the boycott on production and consumption activities and to fine-tune their models correspondingly.[11] The virtue of econometric models is that these adjustments are fed through the model so that an embargo's impact on the economy can be measured. Thus, correction of past error patterns and imposition of informal judgment on econometric models should, in general, yield better forecasts.

The second method of improving econometric forecasts, which entails changing the structure of the model and updating it, could also result in improved forecasts. Econometric forecasts can be refined by trying to incorporate other types of predictive information, such as anticipatory data, into the models. For example, a recent study has shown that incorporating the plant and equipment investment anticipations of the Bureau of Economic Analysis into a model can reduce the forecasting errors of business-fixed investment.[12] To a lesser degree, incorporation of the University of Michigan's consumer sentiment index into a model will improve consumer expenditure forecasts. Including this anticipatory data also improves the ability of models to predict turning points.

Still another way of upgrading the overall performance of econometric models entails "reestimating" the models continuously by adding new observations to the data base and recalculating the equations used for prediction. Most macroeconometric models that are used commercially are reestimated every three to five years. Given their size, reestimating them more often is costly and impractical. Nevertheless, within a three- to five-year period institutional and behavioral changes in the economy could possibly invalidate part of the model. For example, the high rates of inflation in 1974 may have altered economic behavior. Econometric models which were estimated before then would have missed this change. Small macroeconometric models can be reestimated every quarter when national income data are released. However, this type of reestimation alone is not sufficient to reduce significantly the forecasting errors of the models. Upgraded econometric forecasting requires adjusting the model by employing judgment and the analysis of past errors.

Finally, some research in economics is being directed at improving the structure of the models and at using economic data more efficiently in estimating and quantifying

[11]See Donald L. Raiff, "Forecasting in a 'Shortage' Economy," Federal Reserve Bank of Philadelphia, 1974 (unpublished paper).

[12]F. Gerard Adams and Vijaya G. Duggal, "Anticipations Variables in an Econometric Model: Performance of the Anticipations Versions of Wharton Mark III," *International Economic Review* 15 (1974): 267–83.

these models. It is likely that functional relationships can be discovered and refined which will allow modelers to predict specific internal variables more precisely.

WHY USE ECONOMETRIC MODELS AT ALL?

Although econometric models, on their own, cannot track business cycles very well, they do provide an explicit and well-organized framework within which the forecaster can apply judgment to improve their predictive ability. Judgmental forecasters have some implicit model of economic behavior in mind to rely on in formulating their predictions. However, such models are rarely made public along with the judgmental forecasts. The advantage of econometric models is that one can readily pinpoint and, therefore, try to correct weaknesses in the model structure and the assumptions underlying the forecast.

Another important advantage of econometric models is the way in which adjustments feed through the entire model to provide forecasts that are, at all times, consonant with forecasters' theories of how the economy is structured. Obtaining consistent forecasts under a variety of assumptions is more difficult for a judgmental forecaster because the relationships between economic variables in a judgmental "model" are not as clearly defined as those in an econometric model.

Econometric models also help serve up policy menus for economic policymakers. It is relatively easy for an econometric model to provide a range of forecasts made under a variety of policy assumptions. As the impact of changes in Government expenditures and the growth in the money supply are traced through the model, the policymaker can determine the effect of various policies on the economy.

Finally, once a large econometric model has been built, it can be employed for predicting a multitude of economic variables with a small expenditure of time and effort. For example, some current models regularly predict as many as 400 variables. The judgmental forecasting of the same number of variables, on a regular basis, may be very time-consuming.

CONCLUSION

Pure econometric forecasting does not provide very accurate predictions of the timing, size, and duration of business cycles. This is especially true for longer-run econometric forecasts. Nevertheless, forecasters who adjust these models to impose judgmental information and to correct model errors can substantially improve their accuracy. Furthermore, flexibility and continued improvements of econometric forecasting relative to judgmental forecasting do make the efforts channeled into econometric model-building and predicting worthwhile.