Forecasting in Business and Economics

C.W.J. GRANGER

Academic Press
A Subsidiary of Harcourt Brace Jovanovich, Publishers

Forecasting in Business and Economics

C. W. J. GRANGER
University of California, San Diego

ACADEMIC PRESS
A Subsidiary of Harcourt Brace Jovanovich, Publishers
New York London Toronto Sydney San Francisco

ACADEMIC PRESS, INC.
111 Fifth Avenue, New York, New York 10003

United Kingdom Edition published by
ACADEMIC PRESS, INC. (LONDON) LTD.
24/28 Oval Road, London NW1 7DX

ISBN 0-12-295180-8

LIBRARY OF CONGRESS CATALOG CARD NUMBER: 79-91742

PRINTED IN THE UNITED STATES OF AMERICA

81 82 83 9 8 7 6 5 4 3 2

Preface

This text arose from my being asked to give a course on economic and business forecasting to senior undergraduates in the Management Science sequence at the University of California, San Diego. My immediate reaction was to glance at the available texts, but, as so often seems to be the case, I found none that I viewed as acceptable. Some concentrated on just a single forecasting technique; others were just uncritical lists of alternative methods, some lacked depth or content, and some even were wrong. I have attempted to write a text that will provide a clear-cut strategy for tackling a forecasting problem. The importance of the selection of a relevant information set is emphasized together with the question of how to evaluate one's forecasts once they have been prepared. With this strategy in mind, a variety of forecasting techniques and problems, of increasing scope and complexity, are discussed.

I hope that the text will be suitable for senior undergraduates in economics, business, commerce, and management, and also for MBA and starting graduate students in these and other fields, such as operations research and production engineering. Some basic knowledge of statistics is assumed, and I have tried to treat the readers as being both intelligent and motivated. The layout of much of the first half of the book parallels, at a lower level, the recently published *Forecasting Economic Time Series* by Paul Newbold and myself, Academic Press, 1977. Because of the availability of this more advanced and rigorous book I do not attempt to prove every statement made in this text.

The students in my forecasting course have certainly helped in the evolution of the contents of the book, and I would like to thank those who made

constructive comments. I would like to thank Liz Burford for her excellent typing, and I also would like to thank Dennis Kraft and Mark Watson for their careful reading through the page proofs. They must share in the blame for any minor errors that remain, any gross errors must be attributed to the author.

Contents

CHAPTER

1

Basic Concepts of Forecasting

Any astronomer can predict just where every star will be at half past eleven tonight; he can make no such prediction about his daughter.

James Truslow Adams

1.1 A SCENARIO

Consider this statement about a day in the future:

> September 28, 1989, will be a Thursday. By 11 A.M. the sun will be shining brightly on the Scripps Beach at La Jolla, a few miles north of San Diego in California. The surf will consist of four-foot breakers from the southwest at fourteen-second intervals.
>
> It will be high tide, with a height of +2.3 feet. After a brief spell of body surfing and enjoying the 20°C temperature, I shall put on my mask and snorkel and start exploring the kelp beds just beyond the pier. I will find a quarter lost by another diver many months ago and find that a particularly attractive barnacle is attached to it. I use the quarter to buy an *Evening Tribune* and get no change.

This little scenario or view about the future contains a number of predictions or forecasts.[1] These predictions are all time specific, in that a definite time and date are specified, together with a particular location.

There is absolutely no possibility of the scenario being fully accurate about what will occur. At this time one cannot forecast the future perfectly,

[1] The words *prediction* and *forecast* will be considered to be completely interchangeable in what follows.

that is, without error. It does not require much imagination to realize how dull and mentally debilitating life would be if everything about the future were known with complete accuracy. Fortunately, such a possibility is by no means in sight.

Let us now examine some of the details of the scenario:

(i) the date. September 28, 1989, merely specifies when the scenario is to occur.

(ii) the day. That this date will be a Thursday is not a forecast but merely a designation of a name to a date according to a widely accepted method of designating such names, known as the Gregorian calendar. This calendar has given such names to all dates into the indefinite future. An assumption is being made that the same calendar will be in use in 1989.

(iii) tide-height. The mechanism that causes tides is very well known and depends on the movement of the moon and various other members of the solar system. As these movements can be predicted with great accuracy, it is possible to calculate a tide height for virtually any beach in the world, although the calculation is not necessarily an easy one. Thus a forecast of tide height can be made, and one would expect very little error in the forecast, although previous wind conditions may affect the actual value somewhat. The only assumption required to make this forecast is that the tide-generating mechanism does not change in any significant fashion before 1989.

(iv) sun shining, surf conditions, ocean temperature. These can all be considered to be forecasts made by observing what typically happens at Scripps Beach in La Jolla on September 28. For example, one might record sea temperature at 11 A.M. on all previous September 28s for which readings exist, average these values, and use this average to forecast what will occur at the same date in the future. It would clearly be wrong to average temperatures over all past days, as ocean temperature varies greatly from one part of the year to the next, a feature known as the seasonal variation. Clearly such forecasts could be very wrong, but it is difficult to see how they might be improved. Local weather effects in 1989 depend so greatly on the future movements of air masses and the mechanism that moves these masses through the atmosphere is so complicated that there is virtually no hope of making a really accurate forecast of what will occur several years hence. Unlike the astronomers and oceanographers, who have a very high quality model for the movement of planets and oceans, the meteorologist has only a very imperfect model for the atmosphere due to the extra order of complexity involved.

(v) my personal behavior. Much of this is very doubtful, requiring not only that I be around in 1989 and sufficiently healthy to enjoy the ocean but also that I learn how to snorkel. Given that I am sufficiently healthy and

wealthy, the prediction could be self-fulfilling, as I could ensure that I am in La Jolla and do body surf and so forth.

(vi) finding a quarter with a barnacle. This is just pure fantasy. Such a thing could occur but is extremely unlikely. Any detail of this kind can be thought of as being merely the use of artistic license by the writer.

(vii) spend a quarter to buy an *Evening Tribune*. The San Diego evening paper at this time is the *Evening Tribune* and currently costs 15 cents, having gone up from 10 cents fairly recently. By looking at the history of price increases in the economy at large, one might well forecast that what now costs 15 cents will be costing 25 cents by 1989. In fact, such a price is possibly optimistic. There has been a noticeable upward drift in prices, known as a trend, and, by simply assuming that this drift will continue, the price of the paper in 1989 may be estimated. The mechanism by which prices will change is by no means well understood, so the forecast is based on an extension, or extrapolation, of what has been observed in the past.

(viii) use of centigrade. There is one possibly implied forecast in the scenario, that temperatures will be officially measured in degrees centigrade in California in 1989, rather than in degrees Fahrenheit as now. This is an example of a forecast about a change in the way society operates, albeit a very minor one. It is not based on any model of the society or on a great deal of past data but is just a suggestion about the consequences of discussions that are now occurring. In this case, it is not a particularly important forecast, since one can easily convert from centigrade to Fahrenheit without any error, 20°C being equal to 68°F.

Even this simple scenario brings out a number of important points about forecasting. The most important of these is that things to be forecast vary greatly in their degree of predictability. One can have much greater confidence in the forecast for tide height than in that for ocean temperature, and even less confidence in the forecast of the price of an evening paper. Whereas some variables can be predicted with considerable accuracy, others are almost entirely unpredictable, as will be shown later. It should also be clear that the methods that can be used to forecast can vary greatly and will depend upon data availability, the quality of models available, and the kinds of assumptions made, amongst other things. This means that forecasting is generally not easy, which is one reason why the topic is so interesting.

1.2 SOME FORECASTING SITUATIONS

Many million dollars are spent annually on prediction in the United States alone, making forecasting big business. Who forecasts and why? The

major consumers of specific forecasts are government officials and servants, federal, state, and local, together with management, particularly that part belonging to the higher echelons, in all types of business. Some typical forecast situations are the following:

(i) A company has to forecast future sales of each of its products to ensure that its production and inventory are kept at economical levels while controlling the likelihood of being unable to meet orders.

(ii) A firm is considering putting capital into a new investment. To decide whether the investment is a worthwhile one, it has to forecast the returns that will result in each of the next few years.

(iii) A cigarette manufacturing company is considering introducing a new brand and has to predict the likely sales for this brand and also the effect of sales on its other brands.

(iv) A government wants to forecast the values of some important economic variable, such as the unemployment rate, if it takes no action or if it alters one of its controls, such as the marginal tax rate. Such forecasts are necessary for policy decision.

(v) A town council forecasts the demand for junior school places in some part of the town in order to decide whether or not an extra school is required, or if an existing school should be expanded.

Forecasting is by no means confined to business and government, as there are plenty of situations in which some kind of forecasting is needed in the lives of individuals. An example is deciding what career choice will give good total value in terms of job satisfaction and adequate monetary reward. One has to predict how well he will like a job, what kind of advancement possibilities exist, and whether the career is oversubscribed or not. Similarly, if one is making an investment such as buying a house, getting married, or having a further child, it is necessary to ask if the advantages will outweigh the disadvantages and to predict what these will be. These types of predictions are generally very difficult and liable to huge errors and are very rarely made in any formal or specific manner.

It is important to note one common feature of all these forecasting situations—that they lead to *decisions*. The government official, the manager, or the individual requires forecasts in order to decide what to do right now or how to plan for the near future. The forecaster is the producer of information and the decision maker is the consumer. It is clearly important for there to be no misunderstanding between the forecaster and the decision maker about what is being forecast, what information is being utilized, and what assumptions underlie the forecast.

There are, of course, some forecasts that have nothing to do with decisions, such as those that might be contained in an article entitled "Religion

in Iceland in 50 Years Time" or "What Life Will Be Like in the Year 3078." Such offerings may be highly entertaining and are sometimes useful in helping forecasters free their minds from unnecessary restrictions, but they have to be classified with most science fiction as not serious forecasting. The majority of forecasting techniques described in later chapters will be aimed at being useful in decision making.

Exercises

In order to get yourself in the mood for thinking about how the future can be investigated, consider each of the following personal questions and give forecasts:

(a) What will you be doing next weekend?
(b) How will you spend your next summer vacation?
(c) When will you get married, and how many children will you have, if any?
(d) If taking a forecasting course, what mark or grade will you receive in the course?

As a final example of a situation familiar to all students that requires a forecast, suppose you are taking a lecture course from a professor you have not had before. As his or her first introductory lecture drags on, one's mind naturally turns to the question of when the lecture will end. Suppose the timetable indicates that the lecture will start at 10 A.M. and finish by 11 A.M. So that students can get from one class to another, it is generally understood that teachers will finish by ten minutes to the hour. However, from experience you know that some professors so dislike teaching that they finish as early as they dare, while others are (expletive deleted) and so enjoy the sound of their own voice that they keep on going to within a minute or two of the hour, resulting in an unseemly rush to your next class. What forecast do you make about when the lecture will end? As you have very little information to go on, you will probably take a neutral course and guess at 10:50 A.M. but realize that the actual time of finishing will very likely lie in the period 10:40–10:59 A.M. After you have attended the course for a few weeks, you will have gathered some useful information in predicting the time the next lecture will finish. You may have observed, for example, that the lecture always ends between 10:46 and 10:52 A.M., with an average of 10:49 A.M. Thus, an appropriate forecast would be 10:49 A.M., and the expected interval within which the finish time will lie is now much smaller. Thus, the acquisition of relevant information can help greatly in improving the forecast. After a couple of more weeks observation, rather more subtle effects

might be noticeable. You may notice, for instance, that the lecturer has the tendency to follow a longer than average lecture by one that is shorter than average, or you may find that the lectures are generally becoming longer as the sequence continues. Such patterns in the data can obviously be utilized in making improved forecasts. A great deal of attention will be paid in what follows to discussing what information should be gathered and how it should be used, particularly how patterns in the data sequence can be picked out and utilized to form better forecasts.

1.3 TYPES OF FORECASTS

It should already be clear that there are several types of forecasts that need to be made and that they each require different approaches.

The first classification depends on the length of time into the future one is looking. When making statements about the near future, the forecasts are called *short run*, when considering the very distant future, they are called *long run*, and the intermediate case involves *middle-run* forecasts. Such a statement having been made, it now has to be admitted that there is no precise definition of what constitutes short, middle, or long run, as this depends on the variable being forecast and the type of data available, amongst other things. In weather forecasting, the short run might be up to 24 hours ahead, and the long run 2 weeks or more, whereas if one is forecasting an economic variable such as unemployment, short run is up to 10–15 months and long run 4 years and more, although these are purely personal views.

It is generally true that the further ahead one forecasts the less well one does, in that larger errors are likely to occur. The reason for this is that usually the information available for making a forecast is more relevant in the short run than in longer runs.

In the extremely short run, forecasting is often trivial. For instance, if you ask yourself, "Where will I be in two seconds time?" the answer will have to be "Right here, or extremely nearby," as it is impossible to move very far in a couple of seconds. There is frequently a certain momentum in the course of events and this helps greatly in forecasting in the short run but is of very little relevance in the long run. It is also possible to make quite a reputation "predicting" things that have already occurred or have been planned but which are not yet publicly known. Again, such an approach does not help in the long run.

Three important types of forecasts may be called event outcome, event timing, and time series forecasts. These will now be considered in turn.

1.3.1 Event Outcome Forecasts

You know that an event will occur in the future with virtual certainty, but what will be the outcome of the event? For example, consider the following:

(i) A baby is to be born. What sex will it be?
(ii) An election is to occur. Who will win?
(iii) A new brand of soap is to be introduced. Will it succeed? What will its sales be?
(iv) A new premier is about to take over power in Moscow. How will this affect Russian foreign policy?
(v) A new law is about to come into operation legalizing the use and sale of marijuana for adults. What will be the consequences?

The main problem with forecasting the outcome of a future event is that the event may be unique, so that really relevant information may be difficult or expensive to acquire. Take example (i), the sex of an unborn baby. It is very easy to note that in the United States in recent years 51.3% of all babies have been boys and, of course, 48.7% have been girls. Thus, one could make a forecast of the form "with probability 0.513 the baby will be a boy." By observing the proportions of boys and girls born in the families of the mother and father, one might want to alter this probability, since some families produce a predominance of girls, for instance. Much better information could be acquired by performing chemical tests on the mother-to-be and quite possibly a very definite prediction could be made with considerable confidence, particularly as the birth date draws near.

The main approach to event outcome forecasting is to seek or generate relevant data. For example, to predict the outcome of an election one conducts a poll of electors, and to forecast the success of the introduction of a new brand of soap the company will perform various market tests. These are examples of increasing one's information set; the usual limitations to doing this depend on the state of the relevant technology and the cost of gathering the information.

1.3.2 Event Timing Forecasts

This class of forecasts considers questions of the form, when, if ever, will an event occur. Examples are the following:

(i) When will the next British election occur?
(ii) When will the next turning point of the economy happen?
(iii) When will our company's main competitor introduce a new brand?
(iv) When will the company president retire?

(v) When will the bank change its interest rate?
(vi) When will your sister get married?

In some of these cases there exists a sequence of similar events in the past, such as the timing of British elections. By observing the pattern of the times between the events, it might be possible to forecast when the next event will occur. However, the usual procedure is to look for *leading indicators*, which are events that are likely to precede the one we are trying to forecast. For instance, the competitor company may book an exceptional amount of television advertising time or be observed doing market testing, or one's sister may announce her engagement. This approach is used intensively when considering turning points in the economy, as will be discussed in Chapter 7.

1.3.3 Time Series Forecasts

A time series is a sequence of values usually recorded at equidistant time intervals. Examples are

(i) hourly temperatures taken at the base of the Statue of Liberty,
(ii) daily closing prices of IBM shares,
(iii) weekly automobile production by the Chevrolet division of General Motors,
(iv) monthly unemployment rate or balance of payments deficit, and
(v) annual births in California.

As an example of the appearance of a time series, Fig. 1.1 shows the plot of quarterly U.S. Government surplus or deficit figures, using an annual rate, in billions of current dollars, for the period 1952–1974.

Suppose one observes such a time series, denoted by x_t for the value at the time period t, over the period from $t = 0$ up to $t = n$, where $n \equiv$ now. In time series forecasting we are interested in making statements about what value the series will take at some future time period $n + h$, where $h =$ hence. Thus h represents the number of time periods into the future the forecaster is looking. If $h = 1$, then one-step forecasts are being made. For example, if x_t

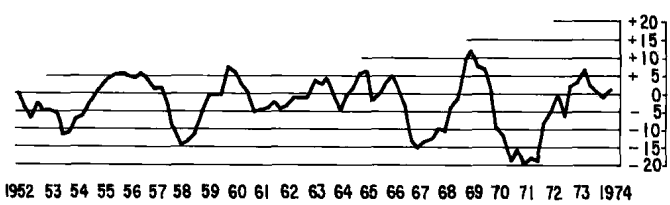

Fig. 1.1 Government surplus or deficit (quarterly).