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INFORMATION, MEASUREMENT, AND PREDICTION IN ECONOMICS

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Abstract

This paper examines the flow of production and use of economic information and analyzes the effects of measurement errors, particularly as transmitted through expectations and forecasts. Economic data are subject to a variety of errors, and the uncertainty about economic measures tends to increase further with the amount and complexity of the processing performed on the underlying data as well as with the distance between the user and the processor. With some exceptions, economic time series lag significantly behind their reference periods and many undergo large revisions. The effective information lag includes not only the time required for incremental data to be produced and transmitted but also the time required for the signals to be extracted by the user. This lag is substantial for many important series.

In general, there is no presumption that the measurement errors are random: Systematic errors are frequent and their sources and forms vary so much that they may be difficult to detect. In times of strong shocks and surprising developments (such as occurred earlier in this decade), measurement of short-term changes in the economy is particularly difficult and current signals are apt to be often misinterpreted. This can result in broadly diffused decision errors which in time are discovered, leading to sharp corrective reactions.

Aggregative predictions from well known and influential sources show certain common patterns of error, which suggests that forecasters react similarly to the observed events and unanticipated shocks. Forecasts of GNP and related variables are adversely affected by errors in both the preliminary data and the base level estimates. There is some support here for the hypothesis that information lags play a significant role in generating business cycles, but it is important to note that the errors involved in predicting the future are typically much larger than the errors involved in estimating the present or recent past.

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Comments welcome

I. On the Nature and Uses of Economic Information

Growth in the modern economy is motivated by the desire to accumulate human and physical resources (capital in the most general sense) and accomplished by actions that necessarily have long-term consequences. The decisions to choose these particular courses of action (strategies) involve similarly long expectations and often large risks of highly variable payoffs. Moreover, knowledge about the distribution of the "states of nature" conditioning the outcomes of such decisions is generally limited: for example, the timing and duration of the next economic slowdown or recession cannot be well estimated from the past incidence of such episodes. Hence, these decisions are typically "difficult" as well as "important." in terms of everyday language. Uncertainty and acting on fallible expectations cannot be avoided. The decisions are based on processes blending various amounts of experience and new learning, information and judgment. Data on the immediate environment of the individual decision maker, relating mainly to current and recent market transactions, are usually essential and the first to command attention, but they are seldom sufficient.[1]

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[1] With respect to current commodities, reasonably competitive and efficient markets provide in the highly economic form of relative prices much of the information required for optimal decision-making. For future goods, however, comparable data generally do not exist for lack of markets that would equate supply and demand of the goods on specific future dates at specific currently-established prices. See Arrow (1974), where this condition is ascribed to the high relative costs of enforcing forward contracts and the inhibiting effects of uncertainty on the willingness to assume strong commitments to future actions.

The economic incentives to reduce uncertainty and improve predictions and decisions give rise to the demand for large amounts of diverse information. This is not a new phenomenon, of course, but it is revealed more clearly than ever in the present era of great advances in informational technology, for now the demand is to a large extent visibly satisfied. The "services of inquiring, communicating, deciding" account for a large and growing proportion of work performed by men and machines in the modern economy.[2] The rapidly growing supply of economic information comes from a bewildering array of private and public sources, reflecting trends in both users' requirements and producers' capacities.[3]

It is impossible to classify economic information by type of use or user: a great many time series and surveys are required by government officials, business managers, and academic researchers alike, for example. It is also impossible to separate neatly data that describe the past from data that anticipate the future: many historical series (e.g., GNP) are in part estimated by extrapolation and many explicitly forward-looking series (e.g., new orders and contracts, index of consumer confidence) tell us something about the past and present. The value of information is not a general discriminative characteristic either, since it depends

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[2]J. Marschak, 1967.

[3]This is well illustrated by the computerized data banks which cover thousands of time series representing all types of variables. Of course, even the largest data banks draw only on the "public" part of the store of information, not on the "private"--confidential and high-cost--part.

on the user's purpose; for instance, business analysts and forecasters put a premium on the most recent data, students of economic history on rare data for the remote past, and model builders and testers on long, internally consistent, and mutually compatible series.[4]

Economic information, then, must be comprehensively defined as consisting of data at various levels of aggregation and processing, from cross-sections of households, firms, and other reporting units to individual and composite time series. In addition to the primary data, economic information includes (1) quantitative, objective measures (e.g., of national income, employment, prices), and (2) measures that quantify judgments of an at least partly subjective nature or are qualitative (e.g., indexes of consumer attitudes and buying plans, capital appropriations and intended investment outlays, credit ratings). Data in the second category, mostly the results of sample surveys, contain important elements of expectations as they sum up assessments of existing conditions and related intentions.

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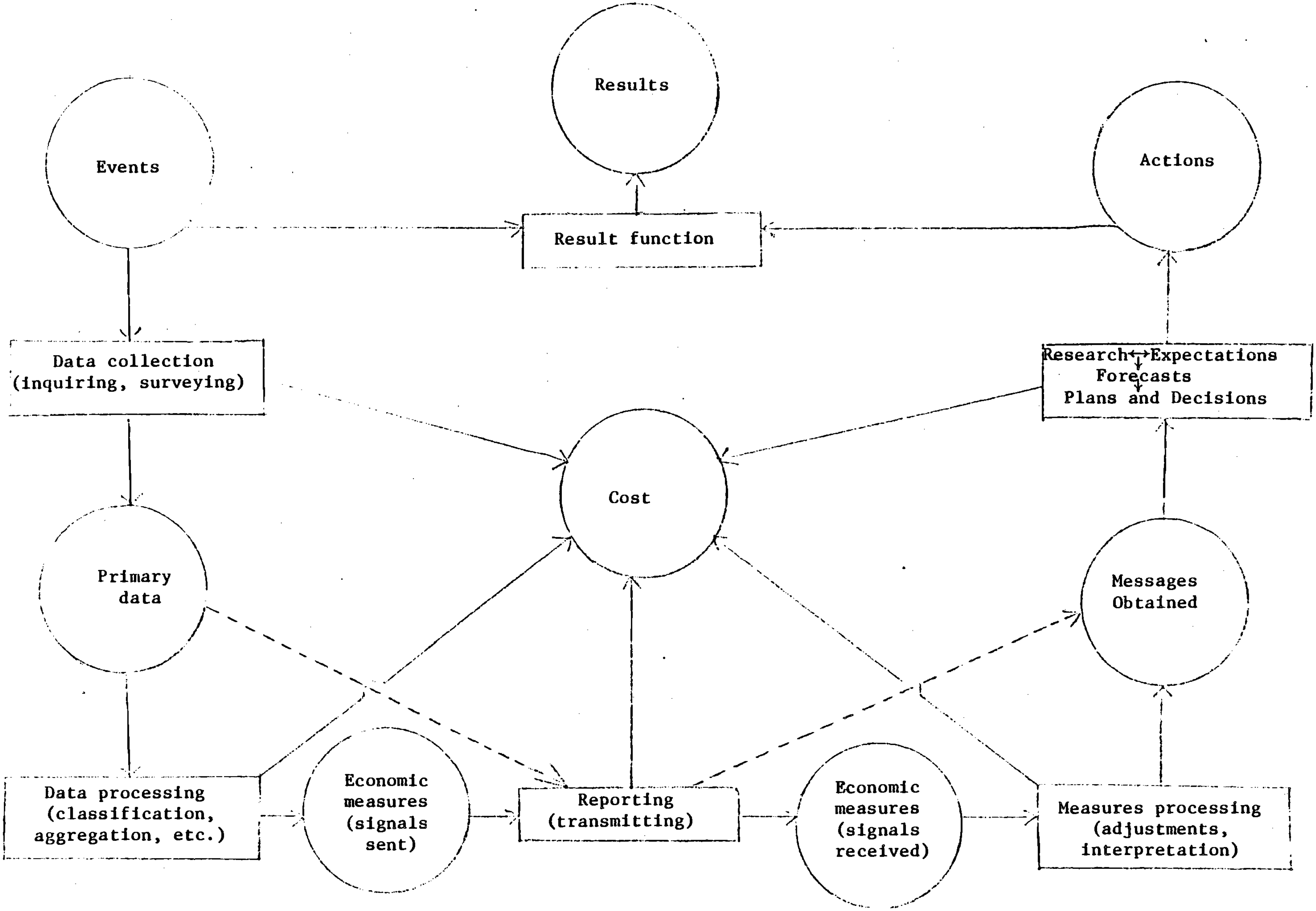
[4]In the last analysis, informational inputs are worth at the margin as much as they contribute to the value of the user's output, whether it is a piece of research, a forecast, or an advice to a decision-maker. But this is a truism, and not very helpful. The calculations involved could be made only long "after the fact" and would certainly be difficult and uncertain in the many cases where no good measures of the benefits and costs of information may exist. This applies particularly to the public information which is not traded and market priced. Complications also arise from the fact that the information-intensive productive processes of research, prediction, and decision-making are often closely interrelated.

The process of compiling and communicating the information proceeds in several stages (Figure 1). First, events are observed and recorded in the form of primary data. This function of data collection, which may also be called inquiring or surveying, is performed for private purposes everywhere in the economy at least in some informal fashion. Public information on the economy, however, is compiled for the most part by government agencies from primary data collected from firms, households, and other units in the private and public sectors. These data are then processed, classified, aggregated, and subjected to various other statistical procedures, e.g., types of "massaging" (interpolation, extrapolation, splicing, smoothing). These operations transform the primary data into the economic measures introduced in the preceding paragraph. It is generally these measures rather than the underlying data that are transmitted to the public by various modes of reporting--releases, telephone, print, etc. In the form in which the economic measures become available to the user, they constitute, from his point of view, "signals" to work with.

The events, data, measures, and signals are variables, generally random. The operations whereby events are transformed into data, data into measures, and measures into signals, can and normally do generate errors--systematic, random, or both.

Fig. 1. The Flow of Production and Use of Economic Information



NOTE: This scheme is adapted from Marschak (1967, p. 5) with changes arising from its being focused on the actual processes of collection, processing, reporting, and using economic information rather than on concepts of engineering communication and statistical decision theory (see text). Circles represent variables (generally random), boxes represent functions or transformations (generally stochastic, involving errors).

The primary data vary greatly in coverage and quality, depending on the knowledge and cooperation of respondents and compilers, but in economics (and other social sciences) they seldom represent the events in question with complete accuracy.[5] Many economic measures are complex aggregates or index numbers, e.g., national income, GNP in constant dollars, index of industrial production, consumer price index; their derivation involves numerous calculations and some approximations and estimations, all of which are subject to various errors. In general, these operations are irreversible, i.e., it is impossible to work back to the underlying data from the given measures.[6]

Substantial improvements in the quality of both the primary data and the derived economic measures have undoubtedly been achieved over the years through increased and better use of sampling techniques and more efficient editing and checking, now powerfully aided by computers. Much has been learned about how to detect and reduce biases and errors in respondents' reports and how to deal with index-number and aggregation problems. Nevertheless, the collection and processing of primary data remain the critical operations in the production of economic measurements and so, not surprisingly, account for most of the defects and errors in the output. The reporting of the results by the agencies that

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[5]Economists who ignore the errors in the data they use, do so at their own peril. In contrast, communication engineers are interested in efficient coding and transmission, not in the deficiencies, of the data. Hence, the theory of information which got its start in the telephone industry (Shannon 1948) assumes that data = events.

[6]This, again, is in contrast to the requirements of the mathematical communication theory (note 5), where encoding transforms data into signals in such a way that the data can be uniquely reconstructed from the code.

produce the information is a lesser source of errors, although the timing, frequency, and formulation of the releases often present difficult problems, particularly for time series that are subject to large revisions.

Where the primary data are reported directly, without being first transformed into indexes, aggregates, or other economic measures, the process is greatly simplified (see the broken lines in Fig. 1, which bypass the "signal" variables and the corresponding transformations). Here the sources of error and the time required to prepare and transmit the information are much reduced, since those inaccuracies and delays that are due to the processing of the data by the producer and to the processing of the resulting measures by the user are naturally eliminated. In some rare cases (the individual common stock prices provide the pre-eminent example), the collected and promptly reported data are virtually error-free, so that the messages received approximate closely the primary data.[7] But as a rule the data contain errors, and the procedures for the derivation of economic measures may actually help reduce these errors, while usually adding others. Moreover, for most purposes of research, forecasting, and decision-making, raw data, regardless of their accuracy, are simply not

[7] The statistical decision theory abstracts from communication problems and analyzes the optimal choice of data producing "experiments" (e.g., sampling) and decision rules. It thus equates the messages received with the data, an assumption to which the above case corresponds rather well.

sufficient and measures representing economic variables and concepts are required. The types of information here considered serve much more often as complements than as substitutes.

Returning to the point at which the economic measures are received as "signals" by the user, it is to be noted first that generally this is by no means the end of the information-transforming process. Even the simplest signals are expressed in symbols that must be "decoded," but economic measures are often far from simple, in part because many concepts of economic analysis are difficult to approximate. One source of the difficulty here is that the responsiveness of the supply of primary data to the changing demands of economic research appears to be on the whole sluggish;[8] another, that the concepts are not always well defined and universally accepted. There is inevitably a great deal of inertia and routine in the massive, manifold, and costly operations of the statistical government agencies so that improvements in their outputs are as a rule partial and gradual. Under these conditions, it is understandable that users often adjust or "massage" these statistics in various ways and interpret the results according to their own preferred concepts (which may deviate from the concepts adopted by the data-producing agencies). Such further processing of the information certainly plays an important role in quantitative economic research, but it is probably frequent in practical business applications as well.

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[8] See Kuznets, 1972, pp. 7-22.

The stock of useful information available to the user depreciates through obsolescence and is replenished by the flow of new data and measures; a net gain over time in that stock increases knowledge. It is normally in this context of relating the new to the old information with the aid of experience, models, or intuition that meaning is extracted from--or imparted to--the new "signals," thus converting them into "messages obtained" (to use the short labels of Fig. 1). Users with different interests, beliefs, or knowledge may obtain different messages from the same signals.[9]

As increments to the working capital of economic information, the messages are inputs into the highly diversified productive processes of research, prediction, and public and private decision making. Thus, they may contribute to research findings, e.g., to an internal analysis of the current business situation prepared by the economic department of a company for the management. By this route or directly, they may influence formal forecasts (e.g., of the business economists in question) or informal expectations (of the same and of management). Information and forecasts (expectations) shape the judgments, that is, assessments of the relevant conditions, which are required for making plans and, eventually, decisions, and they also affect

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[9] To acknowledge this may be analytically inconvenient, but it is certainly an important fact which helps explain, a. o., the dispersion of individual readings of the current economic variables and of expectations of their future values. The crucial role of that dispersion with respect to the behavior of prices and wages is well known from recent developments in the debate on the Phillips curve and the theory of aggregate supply (see Friedman 1968). Expectations are still often treated as if they were single-valued and universally shared, however.

the plans and decisions directly. The nexus is represented in simplified form by the function transforming messages into action through research-expectations-decisions (see the upper right-hand box in Fig. 1).[10]

In many instances, the process whereby decisions produce actions (inaction is included as a particular case) is simple, definite, and observable. This may be so even for some important decisions, e.g., hiring and dismissal of responsible employees in those situations where work force adjustments are under control of the management. It is frequently not so, however, as when uncontrolled variables complicate the process (e.g., government and unions intervene in the labor market) or when a decision leads to a complex and time-consuming action which involves many subdecisions and subactions with an uncertain outcome (consider the decisions to establish a new business, produce a new motion picture, write a new economics textbook). Finally, the results achieved depend as a rule not only on the actions but also on events--changes in the environment of the decision maker. Thus, actions and events can be viewed as joint inputs, and results as output, of a transformation which is a kind of production function.

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[10] Even this brief description suffices to make it clear that economic information (in the form of messages obtained) is a codeterminant rather than a unique determinant of "real-world" actions. Interest in empirically verifiable uses of information, therefore, precludes adopting the simplification that is convenient for the purposes of the communication theory, where actions = messages and the results are good if messages = data, bad otherwise.

For another view of the relationship between information (predetermined variables), expectations, judgments, and plans, see Theil, 1965, pp. 18-22.

In principle, this function accounts for all the result-relevant events and actions properly measured and so, with no basic randomness in behavior, it is deterministic. In practice, at least not all the events are properly measured (or indeed known) and it may be difficult to determine the form of the function. Hence, here, too, there is much room for problems and errors. The results of the uses of economic information are generally uncertain and hard to assess. This is particularly the case when the round trip depicted in Fig. 1 is time-consuming, for then changes in the environment may have occurred that were not correctly diagnosed and prognosed with the available information, so that the actions confront a new set of events, in a sense a changed "present." If the actions have longer consequences, the hazards are still greater because longer forecasts are required. Moreover, some of these consequences will then become events that via the flow of information will influence future expectations, decisions, and actions, so that a feedback loop would have to be considered (for simplicity, the feedback is not shown in Fig. 1).

Data collection, processing, reporting, and uses all have costs that can be measured in terms of dollars spent on, or resources devoted to, these activities. Hence, each of the five functions representing the production and use of economic information contributes to the overall cost variable (Fig. 1). But the direct costs are not the total costs involved: there are also the costs to the user caused by the errors in the information and by improper selection and application of the information. These costs cannot be assessed until the consequences (results) of the decisions and actions taken with the aid of the information are revealed. However, quite apart from the difficulty of measuring these consequences, they are strictly attributable only to the particular action and the events in question (state in which the action was taken). But the observed action might have been produced by a different chain of information and decision functions, and the corresponding result does not depend on which of these functions led to that particular action. This would seem to preclude an unambiguous imputation of the indirect costs to the information functions used. Net returns on the direct costs of these functions can be evaluated, however, if the results (which may be viewed as gross returns on the actions taken) are measurable in the same units as the costs, say dollars.[11]

The broad scheme discussed above with the aid of Fig. 1 accommodates a remarkable variety of sources, types, and uses of economic information: public as well as private services, producing data either "to stock"--for the mass of anonymous users--or "to order"--to satisfy the needs of individual customers; micro- as well as macrodata, quantitative

[11]On a deeper level, in the theory of optimal choice among different sources of information with different costs, difficult problems of valuation are faced and rather strong assumptions are often made, e.g., additive utilities commensurable with dollars are assigned to action results. See C. B. McGuire and Roy Radner, 1972 (especially chaps. 1 and 6).

and qualitative; inputs into research as well as public and private decision making. This wide applicability is, of course, achieved by abstracting from the particular, but it is important to note that there is in fact a great deal of basic structural similarity as well as interaction between what might be called macro and micro information "systems." The transformation of primary observations into systematic measures of certain basic variables (incomes, assets, prices) is typical of the development of information for both the quantitative study of the economy and the managerial decision making. Also, information on the economy at large, itself built up from microdata, is widely used in business, particularly for the increasingly important intermediate- and long-range planning in large corporations; in short, outputs of the national intelligence system become inputs into the microsystems, and vice versa.

Actually, there is no single "system" of economic information in the sense of an organized whole, whether one thinks of the process or of its results; rather, there is an assemblage of many interdependent activities and outcomes, some of which indeed constitute or resemble systems. This entire field of human endeavor has now attained such a size and complexity that the piecemeal scientific attack on it, evident in the rapidly growing literature in several disciplines, may be the best available research strategy.[12] By concentrating on particular segments of the information network and short-cutting others, it is possible to isolate problems and analyze them as though they were independent.[13]

Most of the information-related problems turn out to have strong, often dominant economic aspects, even if they were first treated by engineers, mathematicians, or statisticians. Particularly fruitful in economics, however, is the analysis of the search problem: how to allocate resources in seeking information to be used for a particular purpose so as to achieve optimal results, given an initial condition of incomplete information (uncertainty due to ignorance). For example, a buyer seeking an acceptably low price canvasses sellers until the marginal benefit no longer exceeds the marginal cost of an additional unit of search; a worker similarly canvasses employers in search for higher wage offers; and advertising in product and labor markets, a powerful instrument for spreading price (and other) information, reduces greatly the dispersion of prices and wages, thereby reducing correspondingly the optimum quantity of search.[14] The search theory has many important implications, notably for the explanation of unemployment and the relative speeds of price and quantity adjustments in response to demand fluctuations.[15]

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[12] Formal models of rational choice as applied to problems of information transmission and decision making have been of great interest in recent years to statisticians, mathematicians, economists, psychologists, and others; the role of information in organizational planning and control, and behavioral aspects of information, to scholars in the overlapping areas of operations research and management science, accounting, and computer science.

[13] See notes 5, 6, 7, and 10 and text above.

[14] See Stigler, 1961 and 1962.

[15] Alchian, 1969; Leijonhufvud, 1968, Chap. 2; Mortensen, 1970; Lucas and Prescott, 1974.

What these developments in microeconomics demonstrate is the critical role of information in a market context under conditions of uncertainty.[16] In the search process, market data are sampled directly by the user-decider (sequential sampling is often superior to single-sample procedures). In terms of our flow scheme, the processing and communication stages (the bottom row in Fig. 1) are omitted: data are converted into messages, and the latter into actions by means of optimum rules (cf. note 7 above). This assumes that the data are error free, a simplification rewarded by rigor in the obtained solutions and acceptable for many purposes of the analysis. But here, too, it is well to remember that in actuality data are seldom accurate, e.g., the quoted prices may be distorted by deliberate deception or by the frequently encountered genuine difficulties of measurement and sampling.[17]

The focus of the following sections is on the errors of measurement as they appear in economic information and as they affect economic expectations and behavior, analysis and prediction. The type of information that gets most attention is economic statistics, which generally involve much processing. Measurement of this type may face serious conceptual and technical difficulties even where the underlying primary data are relatively accurate (e.g., consider the index number problem which exists for common stock prices as well as for commodity prices, wages, etc.). The importance of the problems raised by the various deficiencies of economic observations is strongly suggested by a survey of the statistics and the related literature, and further demonstrated

[16]See Hirshleifer, 1973, with a useful list of references.

[17]For a long list of the latter, see Price Statistics of the Federal Government, 1961; Stigler and Kindahl, 1970, is a report on an effort to deal with some of them.

by the lessons of recent history and of an analysis of the data revisions and forecast errors. Of the many uses of economic information, none is more important in the long run than the provision of materials that are indispensable to the scientific progress in economics. Improvements in the validity and reliability of these statistics are much more difficult to achieve than increases in quantity, and much more needed.[18]

II. The Incidence and Influence of Errors in Economic Observations

Types, Sources, and Significance of Errors

Whether acquired by participants in the actual processes of production and exchange or processed and distributed by specialized agencies, information that matters always costs time and other scarce resources; hence, it is not at all necessarily economic (even where it is practicable) to try to obtain all the information bearing on the pending problems or decisions. Models assuming perfect information (which is usually taken to imply elimination of all uncertainty, not only about the past and present but also about the future, in other words, perfect foresight) are therefore intrinsically unverifiable thought-experiments devoid of contact with an essential part

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[18] Much concern has been expressed recently that the role of academic economists in guiding the development of data and measures in accordance with their professional knowledge and needs is being neglected. The more general criticism is that in modern economics abstract theorizing overshadows observation to the detriment of both. See Morgenstern, 1963, passim; Hahn, 1970, pp. 1-2; Leontief, 1971; Worswick, 1972; Phelps Brown, 1972; and R. A. Gordon, 1976. Not all of the critique is well taken or put in a proper perspective, but a significant part surely is. This is not the place to review the issues and the state of the debate (for some in part similarly critical but more general and positive appraisals, see Blackman, 1971, and H. G. Johnson, 1974; for an optimistic long-range view of the new "age of quantification" in economics, see Stigler, 1965, pp. 16-17; and for an emphasis on the contributions of "public" economics, see H. G. Johnson, 1968, and Heller, 1975).

of economic reality. Allowing for the effects of imperfect information is often difficult but ultimately necessary for most purposes. But "imperfect" must mean not only "incomplete" (as it often does in economic analysis) but also "erroneous." Errors in economic observations may be difficult to measure, even detect, and they certainly attract less attention than they should, but there are many indications of their pervasiveness.[19]

Moreover, errors in data and measures, far from being all random, are frequently systematic, but it is in practice difficult to separate these categories. In sampling, systematic error or bias is the error that cannot be reduced simply by taking larger samples. Even probability sampling often fails to eliminate systematic error, though in principle it should, with the aid of proper analysis. Nonprobability sampling is very vulnerable to systematic errors of various kinds, as are the economic measures which, as already noted, usually involve a great deal of data processing. Here the total error may consist of several ingredients that are difficult to assess. There is the conceptual component which reflects the limitations and shortcomings of the concepts underlying the measures as well as the divergences between the measures and the concepts. There is the component of procedural and analytical errors broadly defined, including the errors from data processing and

[19] Kruskal, 1978, documents this statement with many examples and references. Morgenstern, 1963, expands on a long list of criticisms of government statistics in what is probably still the most widely cited book on the subject, but his argument is in some respects and cases one-sided or overstated; see Bowman, 1964, and Morgenstern, 1964.

massaging, aggregation, and computational approximations and truncations. And there is the statistical component of errors due to the gaps and defects in the primary data and to the limitations of coverage. Table 1 attempts to provide a synopsis of all these types of error and their subdivisions, with summary descriptions of sources, assessments, and remedies, and some examples from economics. It proved possible to keep the table simple but not short, self-contained, and self-explanatory as far as it goes, but certainly not exhaustive.[20]

One can find statements to the effect that large systematic errors are easy to spot and remove, hence that they must be relatively unimportant, but this is not correct, for the following reasons. (1) Suppose that the relative neglect of the data limitations and inaccuracy is not merely a matter of casual carelessness, but rather a large-scale phenomenon implying that greater efforts are not believed to be justified by the prospective

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[20] A search of the literature disclosed no conspectus or synthesizing statement of a similar kind, only scattered or more specialized discussions. (Morgenstern's book seems to stand alone, without having evoked much response in the longer run.) In sharp contrast to the paucity of entries in economics, the bibliography on the subject of errors is extensive in natural sciences and psychology (where it embraces both experimental and probability aspects). It is, of course, also extensive in statistics, but mainly for probability sampling: nonprobability sampling receives much less attention and measurement errors even less. For excellent surveys and reference lists, see the articles in the <u>International Encyclopedia of the Social Sciences</u> (1968) by Deming, Stuart, Mosteller, and Ashenhurst.

TABLE 1

TYPES, SOURCES, SELECTED CHARACTERISTICS, ASSESSMENTS, AND CONTROLABILITY OF ERROR IN PRIMARY DATA AND ECONOMIC MEASURES

Type of Error	Sources of Error or Uncertainty about the Data or Measures 1. Errors in Primary Data	Assessments and Remedies
I. Random Sampling Error	Due to random variation: repeated random samples from the same universe or from the same frame (means of access to the universe, e.g., a telephone directory, a membership roster, a map) will give different results.	For adequately large and well designed probability samples, bias from selection of sampling units can be avoided and sampling error can be estimated.
II. Random Measurement Error	Due to a multitude of independent factors causing accidental, nonpersistent, uncorrelated, and partly counterpoised variations, such as: differences among, and mistakes of, personnel collecting and editing the data; fluctuating errors of judgment; random differences between results obtained with different instruments (e.g., in mail, telephone, personal interview surveys); some errors from questionnaires; miscalculations; misprints; etc.	Standard errors in probability sampling are attributable to both sampling and other random errors involved, but it may be possible to estimate some of these separately by proper sample design.
III. Systematic Error in Sample Surveys	Systematic sampling errors are those that cannot be reduced simply by increasing the sample size. They may be: (a) Due to built-in deficiencies or limitations, e.g., the frame omits certain important parts of the universe; the questionnaire fails to ask the right questions or uses inept definitions or classifications or is otherwise poorly designed; the method of test or inquiry is defective so that it fails to elicit the needed information; the (human or mechanical) "instruments" used are similarly defective; the date of a survey has undue effects on some answers; the reports are misallocated over time; etc.	Structural limitations (a) are independent of the size and kind of the sample, and not detectable through recanvasses or sample recalculations. The only remedy is reexamination designed to discover and correct the built-in defects of the survey or method.
	(b) Due to operational errors such as false responses to certain questions; bias from nonresponse; persistent omission of designated, or persistent inclusion of not designated, sampling units; dropouts and "first-time" effects in panel studies; failure of observers to proceed objectively in recording the information collected or handling the missing or defective entries, etc.	Operational errors (b) are not much easier to detect and correct, but better training of observers (reporters, interviewers, coders) can help.
IV. Systematic Measurement (Nonsampling) Error	Due to lapses from completeness and accuracy that will occur even in a most carefully conducted census. Examples: Individuals may be undercounted because of incomplete enumeration of certain categories of households or areas (overcounts are less frequent); mobility of some people may cause problems for reporting residence; fear that the census may have adverse effects for them (e.g., in matters of military conscription, taxation, welfare payments, etc.) may lead some people to evade or falsify their responses; misreporting of particular characteristics (e.g., age); differential effects of method of collecting data (direct enumeration vs. self-enumeration); etc.	Completeness and accuracy are always relative: a perfect census is unattainable. Structural limitations and defects of execution affect a "complete" count as much as a sample, and they may be more important than sampling errors. Ways to meliorate problems include steps to increase public confidence in censuses, research on how to improve questionnaires and enumeration, consistency checks, etc.

TABLE 1 (continued)

Type of Error	Sources of Error or Uncertainty about the Data or Measures 2. Errors in Economic Measures	Assessments and Remedies
V. Conceptual Error	Statistical measures diverge from concepts of economic analysis for various reasons: defects of the underlying data; errors in processing the data and construction of the measures; lack of clear definitions or classifications; disagreements on the concepts (in particular, between the data producing agencies and the economists using the data); differences between the sampled population and the target population from the point of view of the researcher-user of the available statistics. Examples: In national income statistics--problems of defining economic activity, treatment of excluded market transactions (e.g., illegal activities), valuation of depreciation, profits, and inventories, imputations of value to non-market goods and services. Differences between accounting and economic concepts and valuations play a large role here. In index numbers--problems of choosing weights and base dates; for price data, mistaking list prices for transaction prices, treatment of quality changes and new products. In unemployment statistics--problems of definition (what must a person do, or report to have done, to be counted as "looking for work" and unemployed?).	Conceptual errors are often systematic and difficult to assess and correct. Bias can be estimated by the difference between the average value of the given characteristic obtained from repeated investigations and the "true value" that an ideal investigation would disclose. But a true value may not exist or may not be identifiable; e.g., the index number problem has no natural or unique solution. Many conceptual errors, however, can be treated by intensive data analysis, cross checks, and adjustments, and by reconsideration and possibly reformulation of the problem.
VI. Errors in Procedure and Analysis	This category comprises (a) a variety of errors that may arise in the processes of transforming primary data into economic measures or observations. Such processes include interpolation, extrapolation, trend adjustments, seasonal adjustments, splicing, smoothing, approximations with related variables, etc. For example, inter- and extrapolations with related series, used in lieu of not yet available primary data, are presumed to be a large source of errors in the provisional GNP data; seasonal adjustments are often troublesome, as in the recent unemployment figures; some components of the index of industrial production are based on proxies such as shipments, man-hours, and electric power consumption, with adjustments of varying quality.	These errors may be either random or systematic. They too are for the most part difficult to estimate and reduce or control. Again, there is generally no substitute for careful analysis of the data in the context of the given problem. Some of the (a) type errors are presumably eliminated by data revisions.
	Aggregation is technically another such transformation, but because of its great importance aggregation errors (b) deserve to be singled out. They can be serious, particularly in large aggregations (as shown for input-output systems). The simplest such errors arise from misclassifications, but the problem of aggregation is much deeper. Aggregation over time can also be a source of major errors.	Economic theory has some suggestions on aggregation as a subset of model specifications, but it leaves much room for experimentation with different schemes, which may be helpful for reducing these (b) errors.
	Errors of calculations with modern computers (c) can be very serious, particularly in the work with large-scale complex models. What matters is the "generated error" due to the necessity of rounding or otherwise truncating the numerical results of arithmetic operations and the "analytic error" due to calculations for functions that can be computed only approximately (e.g., square root): together with the "inherent error" due to inaccuracies in the initial input data, these errors may interact and propagate through all the steps of the computation. Both generated and analytic errors may remain large even if minimized by computational techniques carrying more precision and using more refined approximations.	Apart from outright human mistakes or blunders, say, in transcribing the input data, the problems of detection and assessment of these (c) errors are far from trivial in large computations where even small relative inherent errors may induce large relative errors in output.

returns over costs (this would indeed appear to be the case). Then large numbers of errors would probably escape attention, including many systematic errors that with some more effort would not. (2) The variety of sources and forms of bias, and the incidence of actual and potential changes in the structure of the measured phenomena, are such that many systematic errors are <u>not</u> in fact easy to identify and correct. (3) Even where such errors <u>are</u> detected and eliminated, this will not be done without some more or less costly and time-demanding process, whether it is searching and learning by transactors, improving statis- cal procedures by data collectors and processors, or research by users of public information. In the meantime, the committed errors will have had some effects on behavior, further observations, decisions, and results.

The distinction between random and systematic errors is important because typically the two types of error have different consequences and require different treatment. In general, those economic and econometric models which recognize errors in variables at all (most do not) proceed on the assumption that the errors are random. The consequences then are well known, the main one being that, when the errors occur in the explanatory variables, the least-square estimates of the regression parameters will be both biased and inconsistent. Correcting for errors is by far the best but also the most difficult way to deal with this problem, particularly when (as is often the case) the "true" values of one or more variables are not directly observable; several other technical ways have been proposed, none easy and all yielding more or less uncertain approximations rather than tested solutions.[21]

Systematic errors are hardly tractable at all other than by detection and correction, and they are potentially much more damaging than random errors. Biased judgments and expectations associated with biased measurement can lead to serious and widespread decision errors that would persist for some time before being discovered (which then might lead to similarly widespread, sharp corrective reactions).

Measurement, Expectations, and Behavior: Some Lessons of Recent History

Striking examples of apparently inconsistent and confusing movements in important time series are furnished by the history of the turbulent first half of the 1970s. The various phases of price and wage controls and decontrols between August 1971 and

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[21] It is generally difficult to find instrumental variables that would be highly correlated with the measured variables and weakly correlated with their errors; moreover, the method assures only consistent, not unbiased, estimation. As an alternative, the maximum likelihood method can be applied, but this requires rather strong assumptions about the measurement errors: that they are normally distributed and that the ratio of their variances (say, in a simple two-variable model with errors in both Y and X) is known. These conditions are usually not fulfilled. For discussions of these and other subsidiary treatments of the problem, see Johnston, 1972, pp. 281-291; Theil, 1971, pp. 607-613; and Intriligator, 1978, pp. 190-193. The classical example of a correction for what are from the theoretical point of view errors in the observed variables is the estimation and use of permanent income in Friedman, 1957.

the early months of 1974 constituted probably the single most important source of data distortions (and by no means only in price statistics), but other factors were at work as well, such as the adjustments to the collapse of the fixed exchange rate system and the energy crisis.

In particular, during 1973-74 expected inflation rates lagged well behind the rapidly rising actual rates, according to all direct survey data known to me; accounting measures grossly overstated corporate profits and understated inventories; and extraordinary divergences appeared between real GNP (which declined between 1973:4 and 1975:1) and industrial production and nonfarm employment (which declined only after June and September 1974, respectively).[22] The always difficult problems of valuation of inventories, fixed capital stock, depreciation, and profits were aggravated by inflation of an intensity unprecedented in decades of U.S. history, and the attempted adjustments (e.g., shifts from the FIFO to the LIFO method of inventory reporting) could not have been and were not promptly and accurately reflected in the published statistics. Total business investment in constant dollars rose and stayed strong long after stock market prices fell and returns turned negative, and long after real consumer outlays on housing and durable and nondurable goods declined decisively. It was only in the second half of 1974 that real business investment turned down, inventory

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[22] For evidence on the developments discussed here and below, see Zarnowitz and Moore, 1977.

liquidation began, and the recession worsened drastically, whereas common stock prices and the constant dollar aggregates for personal consumption expenditures (other than services), retail sales, and housing all show definite downward trends through the years 1973-74. While other factors (notably the low real cost of capital) can also be seen ex post as contributing to the strength of investment at the time,. the overstated profits and overexuberant business expectations may well have played a major role, consistent with the fact that contemporary appraisals of the situation by businessmen and forecasts by economists erred in general strongly on the optimistic side.

The rate of new investment should tend to be positively correlated with (lagged) stock prices, inasmuch as the latter reflect market valuation of corporate assets: ceteris paribus, when that valuation rises relative to the replacement cost of the assets, then the prospective returns to capital improve relative to the user cost of capital, stimulating the demand for plant and equipment.[23] The evidence from time series of an average relation of this sort is on balance favorable,

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[23]This argument underlies the concept of q, defined as the ratio of the market value of installed capital to the concurrent cost of uninstalled capital goods, in Tobin, 1961, 1969. A different interpretation of the same relationship is offered in Fama, 1978, where stock returns are viewed as determined by forecasts of real variables, and especially the change in the rate of real capital expenditures (the latter being in turn determined by the real rate of return on capital, change in output, etc.).

though not very strong.[24] Hence the need to explain the divergent trends in periods such as 1973-74--and here errors of data and expectations contribute plausibly to the explanation. However, it should be remembered that this is not the whole story, for both the stock market and investment respond to economic growth and fluctuations in characteristic but differential ways.[25]

Not only the directly measured price expectations but also short-term interest rates substantially underestimated the rates of inflation in 1973-74. This is important because the hypothesis that capital markets are efficient implies that they optimally evaluate the information pertinent to assess the joint probability distribution of inflation rates, since what matters to the investors is the real return on bills and bonds. The evidence from the Treasury Bill market indicates that interest rates predicted inflation reasonably well over the short range of one to six months ahead in

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[24] For an early empirical use of q-type variables in investment equations for a sample of corporations, see Grunfeld, 1960; for recent uses in aggregate investment functions, see von Furstenberg, 1977; Kopcke, 1977; and Fama, 1978.

[25] While investment expenditures tend to lag at business cycle turns and do not react strongly to minor fluctuations, comprehensive stock price indexes belong to those sensitive leading indicators that usually anticipate not only the recessions and recoveries but also the major accelerations and decelerations in general economic activity. Occasionally, the market moves clearly countercyclically as in 1976-78, when, say, the Standard and Poor's 500 index drifted downward for about 18 months, while real GNP and real business investment continued to rise at not greatly reduced rates. On the stock market as a leading indicator, see Zarnowitz and Boschan, 1975, and Kutzen, 1978.

the period 1953-72, but not in 1973-74, presumably because of large measurement errors in the latter years. This much can be rather confidently stated, even though the stronger conclusions from the tests have been in part successfully contested. Market efficiency tests are of necessity joint hypotheses tests, which complicates their formulation and interpretation; and again, suspected systematic measurement errors in the price and interest rate estimates may have affected the results adversely.[26]

The important question about all types of expectations is what their characteristics actually <u>are</u>, not what they <u>ought to be</u>. An overview of recent forecasts by business analysts and economists is presented at this point; tests of bias and autocorrelations of errors will be considered in the next part of this paper.

Table 2 sums up the evidence on several sets of forecasts of inflation (specifically, the percentage change in the implicit price deflator, IPD) along with the corresponding forecasts for nominal and real gross national product. To provide a needed historical perspective, quarterly predictions over varying spans for the 1970s and two critical subperiods of recession and recovery are compared with each other and with a longer record of annual predictions.[27]

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[26] See Fama, 1976, chap. 6, and comments by Carlson, Joines, Nelson and Schwert, and Fama, 1977. Fama tested the joint hypotheses of market efficiency and of constancy through time of expected real returns on bills. The former receives strong theoretical and empirical support for organized security markets, while the latter is rather arbitrary. Fama attributes the negative results of his tests on data extended through June 1974 to the distortions caused by the price controls that began in August 1971; he also argues (in the 1977 rejoinder) that some of the apparent shortcomings of his model may be due to certain technical data errors in the consumer price index and the security price quotations.

[27] See Zarnowitz, 1979, for further information and more complete analysis of these and other forecasts of percentage changes in GNP, real GNP, and IPD.

TABLE 2

SUMMARY MEASURES OF ERROR IN FORECASTS OF PERCENTAGE CHANGES IN GNP, REAL GNP, AND THE IMPLICIT PRICE DEFLATOR

A. Annual Forecasts, 1963-76 and 1969-76

Line	Forecast Set	GNP MAE (1)	GNP ME (2)	Real GNP MAE (3)	Real GNP ME (4)	IPD MAE (5)	IPD ME (6)
				Annual, 1963-76			
1	Econ. Report of the President[a]	0.9	-0.2	1.0	0.4	1.0	-0.5
2	Michigan Model[b]	1.3	-0.5	1.5	0.2	1.0	-0.6
3	Extrapolations[c]	1.8	-0.6	2.5	0.3	1.3	-0.3
				Annual, 1969-76			
4	Selected Private Forecasts[d]	0.6	-0.4	1.0	0.7	1.3	-0.9
5	Econ. Report of the President[a]	0.8	0.2	1.2	0.8	1.4	-0.6
6	Michigan Model[b]	1.0	-0.1	1.6	0.8	1.4	-0.9
7	Wharton Model[e]	0.9	-0.2	0.9	0.5	1.4	-0.6
8	Extrapolations[c]	2.0	-0.5	3.6	0.7	2.0	-0.2

B. Quarterly Multiperiod Forecasts, 1970-75 and Subperiods

Line	Forecast Set and Span	GNP MAE (1)	GNP ME (2)	Real GNP MAE (3)	Real GNP ME (4)	IPD MAE (5)	IPD ME (6)
				1970:3 - 1975:4			
	ASA-NBER Survey[f]						
9	1 Quarter	0.5	-0.1	0.6	0.1	0.4	-0.3
10	4 Quarters	1.7	-0.4	2.4	1.3	2.3	-1.8
	DRI Model[g]						
11	1 Quarter	0.5	-0.01	0.6	0.3	0.5	-0.3
12	4 Quarters	1.9	0.1	2.8	1.8	2.4	-1.8
13	8 Quarters	2.8	-1.7	5.6	4.7	6.8	-6.8
	Wharton Model[e]						
14	1 Quarter	0.4	-0.1	0.4	0.02	0.4	-0.1
15	4 Quarters	1.7	-0.1	2.0	1.2	2.0	-1.4
16	8 Quarters	3.1	-2.2	4.9	2.9	5.5	-5.3
				Recession, 1973:4 - 1975:1			
	ASA-NBER Survey[f]						
17	1 Quarter	0.6	0.2	0.7	0.7	0.6	-0.6
18	4 Quarters	2.0	-0.4	4.1	4.1	4.9	-4.9
	DRI Model[g]						
19	1 Quarter	0.8	0.3	1.1	1.1	0.9	-0.8
20	4 Quarters	2.5	0.2	4.8	4.8	5.0	-5.0
21	8 Quarters	3.0	-2.5	6.6	6.6	9.4	-9.4
	Wharton Model[e]						
22	1 Quarter	0.3	-0.1	0.4	0.3	0.4	-0.4
23	4 Quarters	1.9	0.03	3.6	3.6	3.9	-3.9
24	8 Quarters	2.9	-2.3	6.2	6.1	8.8	-8.8

TABLE 2
Part B (continued)

Line	Forecaset Set and Span	GNP MAE (1)	GNP ME (2)	Real GNP MAE (3)	Real GNP ME (4)	IDP MAE (5)	IDP ME (6)
				Recovery, 1975:1 - 1975:4			
	ASA-NBER Survey[f]						
25	1 Quarter	1.2	0.3	1.0	-0.3	0.2	0.2
26	4 Quarters	3.0	3.0	4.5	3.7	2.2	-1.2
	DRI Model[g]						
27	1 Quarter	0.7	0.2	0.7	-0.1	0.3	0.3
28	4 Quarters	4.5	4.5	5.6	4.8	2.4	-0.8
29	8 Quarters	1.9	1.9	11.4	11.4	11.1	-11.1
	Wharton Model[e]						
30	1 Quarter	0.6	-0.5	0.9	-0.7	0.3	0.3
31	4 Quarters	4.0	2.9	4.0	2.9	1.6	-0.3
32	8 Quarters	1.7	1.7	8.4	8.4	8.1	-8.1

NOTE: MAE = mean absolute error, ME = mean error (both in percentage points). An individual error is defined as difference, predicted change minus actual change.

[a]Forecasts by the Council of Economic Advisers (CEA) as stated in the *Economic Report*. Based in part on verified inferences from statements in the *Report*.

[b]Source: Research Seminar in Quantitative Economics (RSQE) of the University of Michigan. Based on several working models.

[c]Columns 1-4: Assumes that next year's percentage change will be the same as the average percentage change in the four previous years. Columns 5-6: Assumes that next year's percentage change will be the same as that of the previous years. (In the class of simple extrapolative models for annual data, projections of average change represent an efficient benchmark for GNP and real GNP, while projections of last change are preferable for IPD.)

[d]Average of forecasts from nine sources: Livingston survey, *Fortune* magazine, Harris Trust and Savings Bank, IBM Economic Research Department, National Securities and Research Corporation, Conference Board Economic Forum, R. W. Paterson (University of Missouri), Prudential Insurance Co., UCLA Business Forecasting Project.

[e]Source: *Wharton Economic Newsletter*, Econometric Forecasting Unit, Wharton School of Finance and Commerce, University of Pennsylvania. Based on several consecutive versions of Wharton models.

[f]Median forecasts from the quarterly surveys conducted by the American Statistical Association and evaluated by the National Bureau of Economic Research.

[g]Source: Data Resources, Inc.

The annual forecasts--made near the end of the calendar year for the next year--show reasonably small mean absolute errors and compare favorably with trend extrapolations for both GNP and real GNP (Table 2, Part A). In fact, the MAE decline slightly over time, averaging lower in the period since the early 1960s than in the earlier post-World War II years. Forecasts of inflation are also better than simple extrapolations in terms of MAE, but only by small margins. They tend to underestimate strongly the average inflation rates, much more so in fact than the extrapolations do, particularly in the 1970s. Most of the forecast sets for current-dollar GNP also show negative mean errors. In contrast, the percentage changes in real GNP are on the average overestimated.

The relatively good record of annual predictions does not imply that the more difficult task of forecasting quarterly changes within the year ahead can be performed well, too. Forecasts for the year as a whole can be satisfactory when based on good predictions for the first two quarters; they tend to be more accurate than forecasts with longer spans. In the 1970s, particularly during the recession 1973:4 - 1975:1 and during the early phase of the following recovery 1975:1 - 1975:4, errors of multiperiod predictions cumulated rapidly beyond the spans of two to four quarters ahead (Table 2, Part B). Studies of earlier multiperiod forecasts have shown the cumulation to be as a rule less than proportional to the increase in the span,[28] but in 1973-75 the build-up of

[28]Zarnowitz, 1967, chap. 5 (data for 1947-63).

errors was much greater than usual and definitely more than proportional (that is, involving marginal as well as average errors). This can be traced primarily to (a) the forecasters' failure to anticipate and even promptly recognize the downturn in real GNP and (b) their propensity to underpredict the rates of inflation, particularly over longer spans.

Forecasts from different sources and models all shared much the same kinds of errors in the 1970s. Certainly, few were prepared at the time for the coincidence of high and rising rates of inflation with slowing, then declining real activity, and many were misled by the continuing increase in the nominal aggregates of GNP, sales, profits, etc., especially in the face of temporarily conflicting signals from such important real aggregates as constant-dollar GNP, industrial production, and employment. The apparent conflicts are now understood to derive largely from measurement difficulties associated with the adjustments of GNP for price changes, the use of shipments, man-hours, and electric power series as proxies for physical production, and growth of part-time employment, particularly in the expanding service sector. Careful deflation and analysis of cyclical indicators would have helped, but this is largely retrospective wisdom that was not generally recognized and heeded at the time. All in all, the evidence is consistent with the hypothesis that economic expectations and actions erred on a large scale in this episode, reflecting to a considerable extent the quite real and difficult problems of interpreting the current data.[29]

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[29] Zarnowitz and Moore, 1977.

III. Expectations and Forecasts with Lacking and Lagging Data

Varieties of Predictive Experience and Performance

The formation and characteristics of expectations vary across the economy and over time, since they depend on the institutional and market structure as well as on business and policy conditions. This general statement may be obvious but it has important implications which are often ignored. Uniform and invariant formulas for optimum prediction have little practical value in the economic sphere. On the other hand, the observed differences in forecasting patterns and performance are by and large plausible and consistent with the usual assumptions about economic behavior motivated by self-interest and constrained by scarce resources (including limited information).

Most financial assets are regularly traded in organized auction markets, which are demonstrably efficient, at least in the weak sense.[30] In such markets, highly standardized items are traded by numerous participants, including many resourceful professionals; transaction and storage costs are low; and information, most of which is publicly available, is collected and evaluated continually on a massive scale. New information, therefore, is very promptly reflected in market prices which are flexible and fluctuate widely, so that the price changes are typically not autocorrelated, i.e., not exploitable for predictive purposes. However, most of the goods and services that make up the measured output of the economy are not determined in well organized auction markets,

[30] Certainly there is now much carefully prepared and convincing evidence that current stock prices are "hard to beat" as predictors of future stock prices. See Fama, 1970, and Poole, 1976, for discussion and references.

and no efficient market expectations exist for their prices and quantities. Clearly, it is only reasonable for the forecasting behavior and performance to be quite different for these variables than for the prices and returns determined in the securities and futures markets.

Knowledge of the long-term explicit or implicit contracts, which exist in many product and factor markets, particularly those for labor, would presumably be most helpful to prediction of the variables involved.[31] Unless the contracts are so short or so flexible as to duplicate the effects of spot markets (an unlikely case, for they would then be essentially redundant), they will introduce a measure of "stickiness" into the wage and price formation, which has important implications.[32] Contracts are modified as new information reveals their previously unanticipated costs, but this takes time. In the interim, adherence to the present arrangements would delay adjustments to the new shocks, and thus probably impede to some

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[31] Recent attempts to explain the apparent importance of the contracts stress in various degrees several factors: transaction costs of frequent pricing setting and wage negotiations, including costs of ascertaining profits and other data; high risk aversion of employees; and requirements of maintaining the good will of customers and workers, as perceived by the firms. In this view, most wages and many prices are predetermined, which reduces their flexibility in the short run. Over time, more flexibility is expected and observed, within limits imposed by the costs of collecting the required information and agreeing on its interpretation. The greater the prospective variability of the economy (of output and inflation during business cycles), the more information will be used to reduce the contractual inflexibilities and the shorter will be the prevailing contract periods. For a review of the contractual wage and price theories, see R. J. Gordon, 1976, pp. 207-210; for a different line of criticism, see Lucas and Sargent, 1978.

[32] The most familiar of these is that monetary policy may then influence output in the short run even under rational expectations (Phelps and Taylor, 1977; S. Fischer, 1977), but perhaps the most general one concerns the interaction of contracts with expectations, as noted in the text below.

extent the process of learning which is apt to be a necessary part of the development of a rational expectations model.[33] It would then seem that the effect of temporal contractual rigidities may be similar to that of informational delays. The intuitively appealing argument is that just as a prompt reaction to events produces new information promptly, so delayed reaction works in a way parallel to an information lag. In general, the longer the effective lags that are involved, the more inaccurate are the short-term expectations likely to be. Assuming a lag of, say, k time units, predictions for periods shorter than k may well be biased or show autocorrelated errors even if they are formed rationally, that is, optimally given the available information.

Now the proper concept of an "effective" lag must here include not only the time required for incremental data to be produced and transmitted to the user but also the time required for the signals to be extracted from these data by the user. This lag exceeds the unit period for many economic time series, particularly where the data undergo much processing and revision, are uncertain or volatile and difficult to interpret. One or more of these descriptions apply to most of the important macroeconomic measures.

To illustrate, the GNP data are available only quarterly and then subject to significant lags and revisions. Great uncertainties attach to the meaning of the measured changes in such critical variables as the general price level, national output, the rate of unemployment, and the money supply. Different measures for closely related aggregates

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[33] Here we touch on what is as yet almost a _terra incognita_ of difficult problems, as noted in Lucas and Sargent, 1978. For attempts to deal with learning rules or models in the context of rational expectations, see Grossman, 1975, and Taylor, 1975.

show at times divergent movements, making it difficult to assess contemporary developments (e.g., with respect to the rates of monetary growth and inflation). Some important series are vulnerable not only to estimation errors but also to institutional changes and policy shifts.[34] For most of the monthly indicators, simple calculations suggest that data for at least two-six months are needed to extract from noise those signals that are meaningful in the business cycle context (the quarterly series are often smoother but the effective lags for them must exceed three months, allowing for the timing of the releases, etc.).[35] Much longer recognition lags would presumably apply to disturbances of particular types, e.g., structural shifts, which do not conform to historically observed processes.

Given such uncertainties, individual expectations about the aggregative factors may differ greatly, and there is no trading or other mechanism here to produce consistent and superior "consensus" (in a sense, "market") forecasts. It is true that private economic decisions depend primarily on measures and predictions of microvariables which are often simpler and generally much more familiar to the agents. But there, too, similar signal extraction problems exist, which may be aggravated by the difficulties of distinguishing between the local and the aggregate disturbances.[36] Moreover, expectations on the

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[34] For example, recent changes in banking practices and legislation increased the substitutability of certain types of liquid assets for narrowly defined means of payments, which strongly reduced the importance of M_1, and enhanced that of the broader monetary aggregates.

[35] See Shiskin, 1973, and Handbook of Cyclical Indicators, 1977, Tables 3A and 3B.

[36] These problems have attracted much interest recently on a theoretical level; see Lucas, 1975; Poole, 1976; Kormendi, 1978.

micro level are related to those for particular sectors and for the economy as a whole; the widespread use of economy- and industry-wide forecasts in prediction and planning on the corporate level is well in evidence. Little is known about the effects of these processes of interaction and diffusion, though they presumably matter and could be disturbing.[37] Particularly important are the expectations concerning those data that are selected by the authorities to serve as intermediate targets and instruments of discretionary policies--notably the monetary aggregates and short-term interest rates monitored by the Federal Reserve. The forecasting and operating procedures of the authorities are affected by how frequent, current, and reliable those data are,[38] though their success depends ultimately on the reactions of the economy to the anticipated and actual policy actions.

Tests of Bias and Autocorrelations of Errors

What can be realistically expected of true economic predictions, what desirable properties should they have, and how should they be tested? Recent work on forecast evaluation produced interesting results that bear on these questions, but there are still disagreements on the answers. As suggested by the preceding discussion, the difficulties lie in (a) the

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[37] Phelps and Taylor, 1977, p. 186, refer to a situation in which "the decisions in an industry or sector may be interpreted as signals from which the rest of the economy draws inferences (correct or not) as to the new information causing those decisions. Some question may then arise over the existence of a (stochastic) equilibrium of self-confirming expectations and decision rules."

[38] See B. Friedman, 1977, with discussion.

diversity of situations and problems involved in the predictive uses of limited information, and (b) the quantitative and qualitative differentiation of the available data.

In the case of a repeatedly examined set of price expectations data, findings of apparently systematic errors have led different observers to two opposite conclusions: (1) reject the data as being inconsistent with the rational expectations hypothesis and therefore seriously defective and presumably nonrepresentative; (2) accept the results as a piece of evidence against that hypothesis. But neither of these extreme positions is persuasive, since both overstate the implications of the theory and understate the role of lags and defects of information.

The data are averages from a rather informal semi-annual survey of economic forecasters going back to 1947.[37] As is often the case, the evaluation of these predictions yields mixed results. The errors in forecasts of the consumer price index fail to pass F-tests based on comparisons with selected autoregressive extrapolations, but the errors in the corresponding forecasts of the wholesale price index pass the same tests on the .05 level of significance. Moreover, when compared with predictions from autoregressive equations re-estimated every six months with data available prior to the time of the survey,

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[37] The attraction of these data, compiled by Joseph A. Livingston, a syndicated columnist now with the Philadelphia Inquirer, is their long record. They are, however, difficult to handle because (a) the survey averages were adjusted for the differences between the base values available to the forecasters and the most recent figures released shortly before the publication of the results, and (b) there is some uncertainty about the precise time intervals to which the forecasters intended their predictions to refer. Carlson, 1977, reports on a careful reworking of the Livingston data to take these problems into account. The text that follows refers to Carlson's findings. Earlier studies of this set of data used no timing adjustments (see Pesando, 1975, and Carlson, 1977, for other references).

the forecasts for both indexes are found to be on the average the more accurate. Yet there is clear evidence of substantial underestimation of price rises in periods of wartime-related or other strong outbursts of inflation (in 1950, the late 1960s, 1973-74).

The tests of "rationality" that have been performed on various sets of forecasts are addressed to bias, autocorrelations of errors, and comparisons with selected time-series models. Of these, the latter tests are the most stringent, but they presume that the characteristics of the series viewed as a stochastic process are sufficiently identifiable and stable, which is often not the case because of the limitations of the available data and techniques or changing environment.[38] However, in those cases where the time series properties of the predicted variables are reasonably stable, well known and tested, it is indeed appropriate to require that the forecasts embody these properties: those forecasts that do not are of dubious validity inasmuch as they contain errors whose elimination would have been possible and profitable.

The simplest, frequently applied tests consider the relationship between actual values y and the predicted values $\hat{y}$ in the linear form $y_t = \alpha + \beta\hat{y}_t$, so as to see whether the sample estimates

[38] Estimation of satisfactory time series models requires longer and more consistent data than are available for many economic series. Furthermore, the models are usually developed ex post from revised historical data, often after a long search for best results (with the rejected alternatives being seldom reported). The procedure may then imply that actual forecasts, based on the contemporaneous (at least partly preliminary or estimated) data, are "rational" only if they mimic the results of a formula representing the eventual outcome of one set of such retroactive experiments. Conclusions of this kind are generally not convincing as they disregard not only the data problems but also the possible changes over time in the underlying relationships, the learning behavior of the forecasters, and the role of information other than that contained in the benchmark model.

of α and β differ significantly from 0 to 1, respectively. In practice, F tests are used to examine the joint null hypothesis that $a = 0$ and $b = 1$ in

$$y_t = a + b\hat{y}_t + v_t \quad . \tag{1}$$

Acceptance of the hypothesis means that the criteria of unbiasedness and efficiency are met in the sense that

(2) $E\hat{y} = Ey$ and (3) $\text{cov}(y, \hat{y})/\text{var}\ \hat{y} = 1$,

where E, cov, and var denote expected value, covariance, and variance, respectively. When $\alpha = 0$, the prediction is said to be unbiased; when $\beta = 1$, it is said to be efficient. The latter condition requires that the observed errors $u_t = \hat{y}_t - y_t$ be uncorrelated with the predicted values $\hat{y}_t$. A predictor $\hat{y}$ that satisfies both (2) and (3) may or may not be optimal (for certain linear models of y it is), but $\hat{y}$ that fails to satisfy (2) or (3) cannot be optimal.[39]

While these tests provide interesting information in many cases, it is generally advisable to go beyond them and examine directly the properties of the time series of u_t, the prediction errors. Of particular concern is the question of whether there are any autocorrelations among these errors that could be exploited to improve the forecasts.[40]

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[39] Let $E(y|x) = \alpha + \beta x$ be the expectation of y, the variable to be predicted, conditional upon x, the single explanatory variable, with the joint distribution of (y, x) known. Then $\hat{y} = a + bx$ will meet (2) and (3) if and only if $a = \alpha$ and $b = \beta$. A generalization to the model $E(y|X) = a + B'X$, where X is the vector of explanatory variables is straightforward. For a rigorous development of these ideas and proofs, see Hatanaka, 1974. Mincer and Zarnowitz, 1969, give a statement of the criteria (2) and (3), note their limitations, and provide applications to several forecast sets for 1953-63 (see text below).

[40] On the need for the autocorrelation tests, see Granger and Newbold, 1973.

Analyses of annual forecasts of GNP, business outlays on new plant and equipment, and industrial production for 1953-63 show that the F-ratios are generally not significant at the conventional .01 and .05 levels. However, the samples of forecasts for any given source and variable are small, and the power of the tests is low for any of the alternatives to the joint null hypothesis.[41]

A study of a larger collection of forecasts introduced earlier (see Table 2 and text above) suggests that annual predictions of GNP, 1953-76, do not contain large, systematic errors that could have been readily avoided or corrected in advance. The errors of these forecasts generally have zero or very low autocorrelations.

In contrast, appraisals of the recent quarterly multiperiod forecasts indicate the presence of substantial systematic errors. In a study of 1970-75 predictions of real GNP, IPD, and the unemployment rate, equation (1) was estimated in two ways, by ordinary least squares (OLS) and generalized least squares (GLS).[42] Using OLS, the

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[41]When significance levels of .10 and .25 are used to increase power, it is found that the F-ratios are in many cases significant. The forecasts of personal consumption expenditures show most bias. See Mincer and Zarnowitz, 1969, pp. 11-19.

[42]See McNees, 1978. Quarterly multiperiod forecasts refer to cumulative changes during overlapping time periods ($y_{t+i} = Y_{t+i} - Y_t$, where capital letters denote the <u>levels</u> of the given variable and $i = 1, \ldots, n$ denotes the predictive span). The assumption that the disturbances in (1) are serially uncorrelated is apt to be inappropriate here. A random shock or a measurement error which occurs at t and is not offset in the subsequent n quarters will appear in $y_t, y_{t+1}, \ldots, y_{t+n}$; if unanticipated, it will also appear in $v_t, v_{t+1}, \ldots, v_{t+n}$. Under these conditions, which do not allow for learning on the part of the forecaster, a GLS transformation would be indicated. However, if shock reversals and learning behavior are assumed, OLS will be the preferable technique in certain cases.

joint null hypothesis was rejected by the F test at the .05 level for 17, and at the .01 level for 5, of the 36 regressions examined. Using GLS, the hypothesis was rejected by the corresponding tests for 13 of 17 regressions. These results refer to forecasts made quarterly, for one-four quarters ahead, with the aid of three well-known econometric models, Chase, DRI, and Wharton.

Table 3 presents estimated autocorrelation coefficients $\hat{\rho}_i$ ($i = 1, \ldots, 4$, denoting lags of one to four quarters) for the errors of quarterly forecasts of GNP, real GNP, and IPD for 1970-75. It covers predictions with spans of 1-8 quarters from the same three models and the ASA-NBER surveys (median forecasts). With few exceptions, the first autocorrelation coefficients $\hat{\rho}_1$ exceed in absolute value the standard errors that sample autocorrelations would have in a random model (see cols. 1, 6, 11, 16 and note b).[43] Indeed, the $\hat{\rho}_1$ estimates tend to increase with the span of forecast and are as high as 0.6-0.9 for the predictions looking 4-8 quarters ahead. The higher-order autocorrelations tend to get progressively lower, but the $\hat{\rho}_2$ and $\hat{\rho}_3$ statistics are still large relative to their standard errors in a number of instances, particularly for the longer spans. The chi-square tests for the Q statistics suggest that the probability of the errors not being white noise is often high (at least 90 or 95 percent) for spans of three and more quarters (see cols. 5, 10, 15, and note a). The signs of the autocorrelation coefficients are predominantly positive for small displacements but turn increasingly negative for $i > 3$.[44]

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[43]For additional evidence that first autocorrelations of errors in one-quarter-ahead forecasts are more frequent than could have occurred by chance alone, see McNees, 1978.

[44]The estimates of ρ for the more distant lags are not shown because sampling variability makes them unreliable, given the small size of the available forecast sets. It may be worth mentioning, however, that the lowest estimates are generally those for $\hat{\rho}_4$ and $\hat{\rho}_5$, while those for the longest lags rise in absolute value and are mostly of the order of -.3 or -.4.

TABLE 3

AUTOCORRELATIONS OF ERROR IN QUARTERLY MULTIPERIOD FORECASTS OF PERCENTAGE CHANGES IN GNP, REAL GNP, AND THE IMPLICIT PRICE DEFLATOR, AND THE CORRESPONDING MEASURES FOR ERRORS IN PRELIMINARY ESTIMATES OF THE SAME VARIABLES, 1970-75

Line	Span in Quarters	GNP					Real GNP					IPD					S.E. of β_1[b]
		β_1 (1)	β_2 (2)	β_3 (3)	β_4 (4)	Q[a] (5)	β_1 (6)	β_2 (7)	β_3 (8)	β_4 (9)	Q[a] (10)	β_1 (11)	β_2 (12)	β_3 (13)	β_4 (14)	Q[a] (15)	(16)
									ASA-NBER Survey[c]								
1	One	-.09	-.27	.18	.19	3.29	.37	-.14	-.03	-.10	3.68	.28	.14	.08	-.00	2.30	.21
2	Two	.40	-.23	-.22	-.01	5.49	.57	.05	-.12	-.12	7.48	.66	.27	.12	-.10	11.19	.22
3	Three	.60	.00	-.22	-.08	8.30	.69	.21	.00	-.00	10.40	.79	.43	.12	-.10	16.67	.22
4	Four	.73	.28	.05	-.02	11.67	.77	.41	.24	.14	15.93	.82	.53	.23	-.05	19.16	.23
									Chase Model[d]								
5	One	.37	-.13	-.21	-.12	4.67	.33	-.11	-.14	-.07	3.20	.33	-.02	.15	.07	3.01	.21
6	Two	.40	-.17	-.22	.00	4.98	.49	-.01	-.03	-.00	5.06	.59	.23	.11	-.06	8.75	.22
7	Three	.57	-.07	-.22	-.05	7.61	.68	.21	.08	.08	10.39	.78	.39	.09	-.12	15.66	.22
8	Four	.73	.27	.04	-.04	11.57	.79	.49	.30	.15	18.56	.80	.47	.13	-.11	16.91	.23
9	Six	.76	.51	.23	-.02	15.15	.91	.72	.49	.24	27.95	.82	.57	.34	.12	19.16	.24
10	Eight	.65	.42	.14	-.13	9.53	.87	.68	.45	.16	21.71	.89	.71	.47	.17	23.19	.26
									DRI Model[e]								
11	One	.19	-.12	-.00	.05	1.17	.53	.10	-.09	-.16	7.14	.33	.10	.25	-.10	4.10	.21
12	Two	.52	.06	-.06	-.10	6.04	.64	.20	-.01	-.08	9.58	.57	.24	.14	-.12	8.75	.22
13	Three	.72	.27	-.02	-.10	12.03	.72	.29	.08	.01	12.18	.76	.38	.10	-.14	15.03	.22
14	Four	.80	.44	.15	-.04	16.30	.79	.48	.24	.11	17.56	.77	.48	.17	-.13	16.51	.23
15	Six	.81	.50	.18	-.05	16.00	.91	.72	.48	.23	27.71	.86	.62	.34	.08	21.18	.24
16	Eight	.68	.40	.14	-.09	9.10	.88	.67	.41	.13	19.72	.88	.67	.38	.06	19.20	.27
									Wharton Model[f]								
17	One	-.07	-.37	-.04	.29	5.00	.38	-.09	.10	-.12	3.89	.18	.05	-.12	.20	1.96	.21
18	Two	.27	-.42	-.31	-.01	7.26	.44	-.10	-.24	-.21	6.41	.53	.09	-.05	-.07	6.22	.22
19	Three	.43	-.26	-.39	-.10	8.29	.52	-.04	-.23	-.19	7.22	.61	.27	-.01	-.14	9.29	.22
20	Four	.59	.11	-.13	-.06	7.23	.62	.20	.02	.11	8.30	.73	.33	.06	-.10	12.45	.23
21	Six	.72	.37	.10	-.10	11.48	.79	.63	.40	.18	20.63	.78	.54	.23	-.08	16.31	.24
22	Eight	.63	.25	.11	.06	7.13	.85	.66	.42	.14	20.31	.87	.61	.24	-.03	18.24	.26

TABLE 3 (continued)

Line	Span in Quarters	GNP $\hat{\beta}_1$ (1)	GNP $\hat{\beta}_2$ (2)	GNP $\hat{\beta}_3$ (3)	GNP $\hat{\beta}_4$ (4)	GNP Q^a (5)	Real GNP $\hat{\beta}_1$ (6)	Real GNP $\hat{\beta}_2$ (7)	Real GNP $\hat{\beta}_3$ (8)	Real GNP $\hat{\beta}_4$ (9)	Real GNP Q^a (10)	IPD $\hat{\beta}_1$ (11)	IPD $\hat{\beta}_2$ (12)	IPD $\hat{\beta}_3$ (13)	IPD $\hat{\beta}_4$ (14)	IPD Q^a (15)	S.E. of $\hat{\beta}_1$[b] (16)
							Preliminary Estimates[g]										
23	One	-.30	.03	-.11	.25	3.64	-.27	.20	.07	-.24	3.86	-.25	-.25	-.13	.48	8.19	.21
24	Two	.30	-.32	-.04	.14	4.49	.46	.03	-.05	-.29	4.49	.17	-.60	-.03	.46	12.63	.22
25	Three	.36	.19	-.23	-.01	4.37	.58	.32	-.15	-.27	10.68	.28	-.02	-.20	.26	3.73	.22
26	Four	.52	.25	-.16	-.25	8.00	.51	.25	-.18	-.33	8.81	.59	.28	.03	-.20	8.88	.23
27	Six	.32	.02	.06	.22	2.63	.46	.22	-.17	-.19	5.52	.43	-.16	.01	.26	4.73	.24
28	Eight	.53	.46	.09	.10	7.66	.51	.33	-.21	-.29	7.46	.62	.30	.21	.03	7.79	.26

NOTE: All measures refer to errors in forecasts (lines 1-22) or errors in preliminary estimates (lines 23-28) expressed in form of percentage changes over the given span. $\hat{\beta}_i$ is the estimated autocorrelation coefficient for the lag of i quarters (columns 1-4, 6-9, 11-14).

[a] $Q = n \sum_{i=1}^{4} \hat{\beta}_i^2$ is the Box-Pierce statistic for the first four autocorrelations. Q is approximately chi-square distributed; with four degrees of freedom, the ten percent and five percent points in the χ^2 table are 7.78 and 9.49, respectively.

[b] S.E. for $\hat{\beta}_1 = 1/\sqrt{n}$, where n is the sample size. If all the autocorrelations were zero in the long run, then S.E. for any $\hat{\beta}_i$ would be approximately $1/\sqrt{n}$.

[c] Median forecasts from the ASA-NBER surveys.

[d] Chase Econometric Associates, Inc.

[e] Data Resources, Inc.

[f] Wharton Econometric Forecasting Associates, Inc.

[g] The errors are differences, preliminary minus revised data, and are based on pre-1976 revisions.

The forecasts of GNP are shown in better light by the $\hat{\rho}$ statistics than the real GNP and IPD forecasts are, which agrees with other measures of predictive performance based on these materials (see Table 2 and text above). No substantial differences in the error autocorrelation patterns appear to exist between the four sources of forecasts covered in Table 3 (lines 1-22). This reinforces other findings that indicate the presence of strong elements of common reaction and common surprise among the forecasters.

Moreover, similar autocorrelations patterns emerge when the corresponding measures are calculated for errors in the preliminary estimates of the three variables, that is, for deviations of the preliminary from the revised data (lines 23-28). This suggests that measurement errors, which are presumably reflected in the revisions, may have contributed to the dependencies among the forecast errors.

To my knowledge, all evidence on the quarterly predictions covered in Tables 2 and 3 is consistent with the conclusion that they show much the same configuration of apparently nonrandom errors. These are recorded predictions by some of the most prominent business economists and econometric model builders, which were widely disseminated, purchased, and presumably used at the time, in both the private and public sectors. Other forecasts made public concurrently were not demonstrably more successful. There is no firm proof that any particular forecasting method would have produced more accurate results, although it is clear that some types of prediction such as extrapolations from time-series models are in general unbiased. As of now, the record definitely does not support the claim that business cycle movements and major variations in the rate of inflation can be predicted well over periods of several quarters ahead.[45]

Data Revisions and Forecasting

Current business analysis and forecasting are hampered by the lack of firm knowledge of the present and even of the recent past. For example, the detailed data underlying the benchmark estimates for GNP are obtained at intervals of several years from cross-section surveys (mainly Census Bureau tabulations and IRS tax returns). To get quarter-by-quarter figures with minimum delays, changes in related continuous series (retail sales, business capital outlays, federal government expenditures, foreign trade and payments) are used to interpolate between the benchmarks and to extrapolate beyond them. As a result, the provisional GNP estimates contain errors arising from (1) imprecisions in the benchmark data; (2) inaccuracies in the related series used for quarterly compilations; and (3) inexact or misspecified relationships between the benchmark data and the related series.

The provisional data are revised several times as more complete returns from sample surveys permit extensions of coverage in the time series used as inter- and extrapolators. In addition, major revisions

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[45]As noted earlier, annual forecasts tend to show smaller and less systematic errors, but they do not face the same problems since the short cyclical movements largely average out in the year-to-year changes. Unlike annual changes, the quarterly changes in GNP and, particularly, in real GNP show considerable autocorrelation (even apart from seasonal variation). The rates of inflation are much more highly autocorrelated yet.

occur in the years when new Census data become available for benchmark construction, and on these occasions conceptual revisions are often made in addition to statistical ones.[46]

The statistical revisions reduce mainly one type of error, namely, that resulting from lags in the availability of primary data. About 60 percent of all pre-1965 revisions in GNP and its major components had the effect of bringing the estimates closer to the "final" figures which can be reasonably viewed as the best of the available approximations (though they may still contain significant, if generally unknown, errors). Also, the successive revisions reduced by more than half the variance of the statistical discrepancy between the initial estimates of GNP based on expenditures and income data. In this limited sense, then, most but by no means all revisions do help increase the accuracy of these series.[47]

Even in the ideal case of ultimately perfect data, economists could not ignore all measurement problems: for example, expectations which play a major role in economic life are to a large extent based on provisional information and hence influenced by the lags and errors involved. Business analysts and forecasters must use

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[46]Specifically, GNP releases issued in each month of quarter t provide successive sets of advance and provisional data for quarter $t - 1$ (called, respectively, the 15-, 45-, and 75-day release). Then there are two or three annual July revisions and finally one or more benchmark revisions. Also, revisions in the seasonally adjusted data are made frequently. The seasonal adjustment factors must themselves be first predicted, but they can be more accurately estimated once data covering a full year are in hand; hence, the July revisions are particularly important here.

[47]For historical evidence, see Cole, 1969a. Further studies on other and more recent data seem sorely needed in this area.

provisional estimates, and frequent revisions, whether or not successful in reducing errors, inevitably complicate and sometimes frustrate their efforts.

Let $y^o_{t-i} = y_{t-i} + \eta_{t-i}$, $i = 1, 2, \ldots,$ be the series of estimates available to the forecaster at time t. These values are provisional estimates for the most recent periods (small i's) and at least once revised figures for the earlier periods. For sufficiently large values of i, the observational errors η_{t-i} are normally zero. As a rule, it is just such mixed-vintage series y^o, not the "final" revised series y, that serve as inputs to active econometric models and in the work of current business analysts and forecasters generally.

Early appraisals of recent forecasts must use the provisional data for the actual values, which yields the <u>first estimates of the forecast error</u> defined as $\varepsilon_t = \hat{y}_t - y^o_t$. Historical evaluations may use the final data, which leads to a determination of the <u>revised estimates of the forecast error</u> as $u_t = \hat{y}_t - y_t$. The two measures of forecast error and the observational error η are linked by a simple additive relation:

(4) $$u_t = \hat{y}_t - y_t = (\hat{y}_t - y^o_t) + (y^o_t - y_t) = \varepsilon_t + \eta_t \quad .$$

For the means of the three error terms, it follows that

(5) $$\bar{u} = \bar{\varepsilon} + \bar{\eta} \quad ,$$

where $\bar{u} = \frac{1}{n}\sum_{t=1}^{n} u_t$ and $\bar{\varepsilon}$ and $\bar{\eta}$ are defined analogously. For variances, (4) implies

$$(6) \quad \text{var } u = \text{var } \varepsilon + \text{var } \eta + 2 \text{ cov}(\varepsilon, \eta) \quad \text{or} \quad s_u^2 = s_\varepsilon^2 + s_\eta^2 + 2rs_\varepsilon s_\eta \quad ,$$

where $s_u^2 = \frac{1}{n} \sum_{t=1}^{n} (u_t - \overline{u})^2$, etc., and r is the coefficient of correlation between ε_t and η_t. Taking second moments around zero yields

$$(7) \qquad M_u = \overline{u}^2 + s_u^2$$

as the mean square error for u; M_ε and M_η are defined analogously. It then follows from (5) and (6) that

$$(8) \quad M_u = (\overline{\varepsilon}^2 + s_\varepsilon^2) + (\overline{\eta}^2 + s_\eta^2) + 2(\overline{\varepsilon}\,\overline{\eta} + rs_\varepsilon s_\eta) = M_\varepsilon + M_\eta + 2M_{\varepsilon\eta} \quad .$$

The decomposition (8) is informative in that it takes account explicitly of all the relevant elements of bias, variance, and interaction terms.[48]

All these expressions are for sample statistics; the counterparts of (4) and (8) in terms of population parameters are (4') $Eu = E\varepsilon + E\eta$ and (8') $Eu^2 = E\varepsilon^2 + E\eta^2 + 2E(\varepsilon\eta)$. Sampling variation alone could make the calculated means or the estimated r coefficients differ from zero even if the data and forecasts were really unbiased or their errors uncorrelated. Tests of significance are therefore indicated.

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[48] In the case of no biases, (8) reduces to (6). In the case of $r = 0$, $s_u^2 = s_\varepsilon^2 + s_\eta^2$, so that pure predictive accuracy is properly measured in terms of ε and is understated in terms of u which incorporate estimates of measurement error η.

The importance of errors in provisional data is demonstrated by the following measures for equations (5) and (8), which refer to the forecasts of annual levels of GNP in 1953-63.[49]

	$\bar{u}$	= $\bar{\varepsilon}$	+ $\bar{\eta}$	M_u	= M_ε	+ M_η	+ $2M_{\varepsilon\eta}$
Billions of dollars	-10.0	-5.2	-4.8	229.9	136.8	39.3	53.8
Percent				100.0	59.5	17.1	23.4

The error terms ε_t and η_t tend to be both negative, since the forecasts underestimated the provisional GNP figures and the revisions raised the latter in most years. The t-tests for $E\varepsilon = 0$ and $E\eta = 0$ indicate that the biases are significant at conventional levels for several forecast sets and the corresponding data. The interaction term $2M_{\varepsilon\eta}$ is positive and substantial as is its bias component $2\bar{\varepsilon}\,\bar{\eta}$, which dominates the other component $2rs_\varepsilon s_\eta$; the $r_{\varepsilon\eta}$ coefficients are mostly negative and near zero or small. The η errors show sizable positive autocorrelations, which implies that the errors would tend to be offsetting when the preliminary data are used both as inputs into the forecasts and as realizations with which the forecasts are compared.[50] Predictions that

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[49] Here measurement errors are $\eta_t = y_t^o - y_t$, where y^o denotes the first estimates of GNP for the preceding year and y denotes the data from the August 1965 benchmark revision. The first observed forecasts errors are $\varepsilon_t = \hat{y}_t - y_t^o$, where $\hat{y}$ stands for the weighted average forecasts of GNP based on the data listed and described in Zarnowitz, 1967, Table 1 and text, pp. 12-16. These are mainly judgmental forecasts from various business and academic sources. They are combined into averages weighted by the number of years covered by each of the forecast sets. All errors are computed by subtracting the actual from the predicted values.

[50] For the development of this argument and supporting evidence, see Cole, 1969b, especially pp. 56-57, and Zarnowitz, 1967.

rely heavily on such data would therefore be expected to show smaller average errors when evaluated against early figures than when evaluated against revised figures, and this is indeed the case for most of the forecasts of GNP and its major expenditure components covering the 1950s and 1960s. For example, in the summary above, $\bar{\varepsilon}$ is little more than half the size of $\bar{u}$, absolutely, and M_ε is about six-tenths of M_u.

It is useful to analyze forecasts of changes as well as of levels. If the initial level ("base") from which a change is predicted is known in terms of preliminary data y^o, while the outcome of the forecast is evaluated in terms of the revised data y, the error in predicting change between t and $t + i$ is

$$(9) \quad u_{\Delta t+i} = (\hat{y}_{t+i} - y^o_t) - (y_{t+i} - y_t) = (\hat{y}_{t+i} - y_{t+i}) - (y^o_t - y_t) = u_{t+i} - \eta_t \quad .$$

This illustrates the rule that the level error equals the total change error plus the base error. But (9) oversimplifies the forecasting situation most likely to be encountered in practice. Typically, even y^o_t is unknown and the j-th forecaster must make his or her own estimate of the base, say, y^j_t. Then

$$(10) \qquad u_{\Delta t+i} = (\hat{y}_{t+i} - y_{t+i}) - (y^j_t - y_t) = u_{t+i} - \varepsilon^j_t - \eta_t \quad ,$$

where $\varepsilon^j_t = y^j_t - y^o_t$. If the outcome of the forecast is evaluated in terms of the preliminary data, the corresponding formula is

$$(11) \qquad \varepsilon_{\Delta t+i} = (\hat{y}_{t+i} - y^o_{t+i}) - (y^j_t - y^o_t) = \varepsilon_{t+i} - \varepsilon^j_t \quad .$$

The history of the GNP forecasts reveals a preponderance of underestimates of both the base levels and the changes, which add up to larger average errors of the same type in the future levels. This is illustrated in the tabulation below, which uses decomposition (11), with i = 1 for annual data.[51] However, industrial production

	Mean Error (ME)			Mean Absolute Error (MAE)		
	Base	Change	Level	Base	Change	Level
GNP, 1953-63 (bil. dollars)	-2.1	-3.2	-5.2	2.9	8.4	10.0
GNP, 1953-69 (bil. dollars)	-3.5	-3.8	-7.3	3.8	8.5	10.6
Real GNP, 1953-63 (1947-49 = 100)	-0.9	-1.4	-2.3	1.2	3.6	4.1
Indus. Prod., 1953-63 (1947-49 = 100)	0.8	-0.8	-0.09	1.3	4.1	4.3

forecasts from the same sources are different in that here, errors of base and of change often disagree in sign, which helps reduce the level errors. Monthly data provide more current information than quarterly data, which gives an advantage to the forecasts of industrial production relative to those of GNP. But the general conclusion, based on reasonably comprehensive and representative materials, is that base errors affect importantly most aggregative predictions. As shown by the summary above, they amount to about 30 percent of the corresponding level errors when averaged without regard to sign. Although the base forecasts are on the whole close to the earliest government statistics for the same periods, and are indeed frequently no less accurate than

[51] The descriptions and measures for each of the forecast sets used are given in Zarnowitz, 1967, chaps. 2 and 4 with Table 4, pp. 33-34 (for 1953-63) and in Zarnowitz, 1972, pp. 203-206 with Table 1 (for 1953-69). See also footnote 49 above.

the latter,[52] it is clear that the forecasters' imperfect knowledge of the present contributes substantially to their errors in predicting the future.

A simple and effective way to minimize the effects on forecasts of the base revisions is to express the predictions and their errors in terms of percentage changes.[53] Thus viewed, the annual predictions of GNP earn good marks for overall accuracy when judged according to realistic standards (see Table 2 and text above). The errors in predicting percentage changes in GNP, real GNP, and IPD all average close to one percentage point for 1963-76 (see the MAE figures for the ε-type errors in the accompanying summary).[54] Data errors, however, are by no means negligible even when assessed on this plan: the MAE for the corresponding η series are about one-third of one percentage point.

	GNP		Real GNP		IPD	
	MAE	ME	MAE	ME	MAE	ME
Forecast errors (ε) Percent. points	0.9	-0.5	1.2	0.3	1.0	-0.6
Data errrors (η) Percent. points	0.3	-0.3	0.4	-0.1	0.4	-0.3

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[52] Cole, 1969a, pp. 29-35.

[53] Indeed, there are several good reasons for this type of approach. Percentage changes often depend less on the levels and are more stable and comparable over time than absolute changes. This is particularly important for variables with strong trends. Moreover, it is the rates of growth in income, output, price level, etc., that are of principal interest to analysts and policy makers.

[54] Here the forecast errors ε_t equal predicted percentage changes minus actual percentage changes, where the latter are based on first official estimates for the preceding year. The data errors η_t equal the percentage changes in the same preliminary estimates minus the corresponding changes in revised figures taken from the May 1977 Handbook of Cyclical Indicators.

Unlike in the 1950s and 1960s, when GNP forecast errors and data errors tended to agree in sign so that $|\bar{u}| > |\bar{\varepsilon}|$, $M_{\varepsilon\eta} > 0$, and $M_u > M_\varepsilon$ (see pp. 48-49 above), in the first half of the 1970s the signs of ε_t and η_t differed most of the time, causing opposite results. While forecasters overestimated real growth, the early data for constant-dollar GNP often showed less growth than the revised data (note the signs of $\bar{\varepsilon}$ and $\bar{\eta}$ in columns 7 and 8 of Table 4, respectively). While forecasters underestimated inflation, early data for IPD systematically showed more inflation than the revised data (cf. cols. 13 and 14). For GNP, the results are more mixed, but most of the $\bar{\varepsilon}$ values are negative, most of the $\bar{\eta}$ values positive (cols. 1 and 2). The $M_{\varepsilon\eta}$ terms are, with few exceptions, negative (cols. 5, 11, and 18), reflecting the signs of cov(ε, η). As a result, $M_u < M_\varepsilon$ for most of the forecasts covered in Table 4, including about two-thirds of those for GNP, slightly more than half of those for real GNP, and all of those for IPD. In other words, the quarterly multiperiod predictions for 1970-75 show smaller average errors when compared with revised data than when compared with provisional data.

Since the current quarterly econometric models are implemented with revised data except for the most recent observations, one might argue that the above result is not surprising for the forecasts produced with the aid of these models. The point has some validity but it is blurred by the common practice of judgmental adjustments, which are demonstrably important to econometric forecasting and are likely to reflect information about some late events.[55] Also,

[55] Zarnowitz, 1972, pp. 197-198 and 218-222.

TABLE 4

DECOMPOSITION OF MEAN SQUARE ERROR IN QUARTERLY MULTIPERIOD FORECASTS OF PERCENTAGE CHANGES IN GNP, REAL GNP, AND THE IMPLICIT PRICE DEFLATOR: ERRORS IN PROVISIONAL ESTIMATES AND IN FORECASTS, 1970-75

Line	Span in Quarters	GNP						Real GNP						IPD					
		$\bar{\epsilon}$	$\bar{\eta}$	M_ϵ	M_η	$2M_{\epsilon\eta}$	M_u	$\bar{\epsilon}$	$\bar{\eta}$	M_ϵ	M_η	$2M_{\epsilon\eta}$	M_u	$\bar{\epsilon}$	$\bar{\eta}$	M_ϵ	M_η	$2M_{\epsilon\eta}$	M_u
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
								ASA-NBER Survey											
1	One	-.06	-.00	4.78	.08	-.05	4.80	.10	-.02	.54	.11	-.06	.59	-.26	.01	.34	.06	-.16	.24
2	Two	-.27	.01	1.61	.12	-.18	1.55	.32	-.02	2.42	.16	-.23	2.35	-.64	.03	1.50	.10	-.33	1.27
3	Three	-.38	.01	3.34	.17	-.33	3.18	.76	-.03	5.97	.28	-.51	5.74	-1.20	.05	4.30	.11	-.58	3.84
4	Four	-.39	.05	4.85	.18	-.28	4.74	1.30	.02	10.83	.33	-.39	10.77	-1.82	.04	8.89	.08	-.73	8.24
								Chase Model											
5	One	.01	-.00	.34	.08	-.07	.35	.17	-.02	.48	.11	-.10	.49	-.15	.01	.31	.06	-.17	.20
6	Two	.04	.01	1.83	.12	-.18	1.77	.51	-.02	2.15	.16	-.17	2.14	-.49	.03	1.65	.10	-.41	1.34
7	Three	.02	.01	4.09	.17	-.31	3.95	.92	-.03	5.75	.28	-.38	5.65	-.96	.05	4.18	.11	-.61	3.68
8	Four	.08	.05	5.94	.18	-.29	5.83	1.45	.02	11.15	.33	-.47	11.01	-1.50	.04	9.01	.08	-.84	8.25
9	Six	-.66	.14	9.62	.26	-.39	9.50	2.38	.13	28.30	.33	-.23	28.40	-3.31	.02	26.49	.17	-1.95	24.71
10	Eight	-2.34	.29	13.97	.28	-.86	13.38	2.82	.25	44.83	.31	.93	46.06	-5.48	.02	54.07	.14	-2.62	51.59
								DRI Model											
11	One	-.01	-.00	.47	.08	-.12	.43	.26	-.02	.64	.11	-.07	.68	-.27	.01	.45	.06	-.15	.37
12	Two	.11	.01	1.88	.12	-.19	1.82	.77	-.02	3.31	.16	-.32	3.16	-.70	.03	1.93	.10	-.35	1.68
13	Three	.05	.01	4.20	.17	-.30	4.07	1.20	-.03	8.13	.28	-.59	7.82	-1.22	.05	4.64	.11	-.82	3.94
14	Four	.11	.05	7.17	.18	-.13	7.22	1.82	.02	14.58	.33	-.40	14.52	-1.85	.04	9.53	.08	-.99	8.63
15	Six	-.42	.14	9.68	.26	-.08	9.86	3.16	.13	30.87	.33	-.17	31.37	-3.88	.02	27.90	.17	-1.73	26.34
16	Eight	-1.69	.29	8.38	.29	-.20	8.47	4.71	.22	51.93	.30	2.80	55.03	-6.78	.05	67.65	.13	-2.55	65.23
								Wharton Model											
17	One	-.12	-.00	.29	.08	-.07	.30	.02	-.02	.40	.11	-.05	.46	-.14	.01	.23	.06	-.18	.11
18	Two	-.10	.01	1.88	.12	-.33	1.67	.35	-.02	2.52	.16	-.41	2.28	-.46	.03	.94	.10	-.36	.68
19	Three	-.19	.01	4.41	.17	-.34	4.24	.72	-.03	5.29	.28	-.49	5.08	-.96	.05	2.78	.11	-.52	2.37
20	Four	-.12	.05	5.11	.18	-.21	5.07	1.22	.02	7.81	.33	-.45	7.68	-1.44	.04	6.15	.08	-.66	5.57
21	Six	-.69	.14	7.00	.26	.16	7.43	2.17	.13	17.59	.33	.17	18.09	-3.08	.02	19.75	.17	-1.44	18.48
22	Eight	-2.17	.29	11.40	.28	-.36	11.32	2.90	.25	35.78	.30	1.46	37.54	-5.34	.02	47.58	.14	-2.14	45.58

NOTE: See text and Table 3 for explanations of the data and symbols used.

as shown before, the pre-1970 results are quite different for econometric as well as other predictions. It is well established that the accuracy of all types of forecasts depends critically on the differential economic characteristics of the periods covered, and data errors, which are partly in the nature of extrapolation errors, may also vary significantly with such characteristics.[56]

The quarterly data covered in Table 4 are based on pre-1976 revisions. Had we used the major benchmark revisions published in January 1976, which introduced several important conceptual changes in the national income and product accounts, the η errors would have been about twice as large on the average (without regard to sign). The summary measures of the size and role of data errors ($\overline{\eta}$, M_{η}, $M_{\epsilon\eta}$) tend to increase in absolute value over longer predictive spans, but only irregularly and much less than the measures for the forecast errors ($\overline{\epsilon}$, M_{ϵ}). As a result, data errors, although substantial as such, are small in comparison with the forecast errors in the period 1970-75; and M_{ϵ} dominates M_{η} in the decompositions of Table 4, particularly for the longer predictions.

In general, the common complaints of macroeconomic forecasters about the size and frequency of revisions in GNP accounts (and some other aggregate statistics) make sense in light of the high probability that large improvements in the accuracy of preliminary data would result in significantly better predictions. But such improvements are costly and difficult to achieve. What economists themselves can more readily do is to

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[56] Zarnowitz, 1979; Cole, 1969a.

make more efficient use of the available data by exploiting for predictive purposes the relationships between the preliminary and the revised estimates. Proposals to this effect are of very recent origin but they deserve much careful attention.[57]

IV. Summary and Conclusions

The activities and products of information, measurement, and prediction are essential to the contemporary U.S. and other highly developed countries, but it can hardly be claimed that they are well documented or understood. Although very diversified, they are so interrelated that it is advisable to treat them jointly as a research subject. Accordingly, much ground had to be covered in this paper, from an overview of the flow of economic information to a selective analysis of measurement errors and their economic effects, particularly as transmitted through expectations and forecasts. Only a brief summary statement and some suggestions for further study are needed here to conclude the report.

1. Economic data are subject to errors due to inadequate sampling, concealment, falsification, poorly trained collectors, and various other reasons. Further, there is much uncertainty about economic measures, which tends to increase with the amount and complexity of the processing performed on the underlying data and with the distance between the user and the processor. Some important information, notably the price data for financial assets traded in organized auction markets, is both prompt

[57] See Howrey, 1977.

and generally accurate, but most is not: as a rule, economic time series lag well behind their reference periods and many undergo large revisions. The effective information lag includes not only the time required for incremental data to be produced and transmitted but also the time required for the signals to be extracted from these data by the user. For most economic time series, which are noisy, this lag exceeds the unit period and is measured in months.

2. In general, there is no presumption that the measurement errors are random: systematic errors are frequent and their sources and forms vary so much that they may be difficult to detect. Biased measurement may lead to biased judgments and expectations, hence to serious and broadly diffused decision errors. It takes some time before such errors are discovered, and the corrective reactions which then follow are apt to be sharp and similarly widespread. In times of strong shocks and surprising developments, measurement of short-term changes in the economy is particularly difficult and current signals are often liable to be misinterpreted. For the period 1970-75, contemporary time-series data, business conditions reports, and forecasts provide substantial evidence in support of these statements.

3. Aggregative predictions from well known and influential sources show certain common patterns of error, which suggests that forecasters react similarly to the observed events and unanticipated shocks (they also interact, but it is difficult to assess the relative importance of these factors). The quarterly multiperiod forecasts for 1970-75 show errors that cumulate strongly with the span of the prediction and

are autocorrelated for the longer spans. Forecasts of GNP and other variables measured with significant lags and subject to substantial revisions are adversely affected by errors in both the preliminary data and the base level estimates. There is some support here for the hypothesis that information lags play an important role in generating business cycles, but it is not very strong. It is important to note that the errors involved in predicting the future are typically much larger than the errors involved in estimating the present or recent past.

4. It is one thing to argue that economic measurement problems are serious and deserve much more attention from the profession than they now receive, and quite another thing to specify what exactly should be done about it. The fact is that there are no simple or well established ways of dealing with the effects of deficient information on economic expectations, analysis, and behavior. But this is surely no excuse for ignoring the problems involved. Assessments of the significance and quality of the data for a given purpose are part and parcel of the task on hand, and they can be very instructive. Replications of economic calculations with different sets of data should also be encouraged and publicized for they perform important verification functions. A study of some assembled materials on such assessments and replications is under consideration as a sequel to this paper.

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