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**President's Report
and Papers Presented
to the Board of
Directors at the Spring
Meeting, 1972**

**TOWARD A NEW MICROECONOMICS
JOHN R. MEYER**

If in the past year many men suffered ennui, economists certainly did not. Indeed, for economists and economics the second half of 1971 and first half of 1972 unquestionably formed one of the most interesting periods since the end of World War II.

It was also an eventful time for the National Bureau. Our research expenditures increased significantly. Specifically, our total budget for the fiscal year 1973 is 70 per cent greater than that for fiscal 1971. Roughly two-thirds or a bit more of this increase is a result of the inauguration of the NBER Computer Research Center for Economics and Management Science. The establishment of this Center is one of the major new departures in our work program in recent years. Another important development, also largely concerned with the application of the computer to economic research, has been the launching of the *Annals of Economic and Social Measurement*. These innovations are the focus of the two reports immediately following this one. So I shall not expand on them here.

Rather, I would like to consider to what extent changes in the Bureau's research activity have responded to, or anticipated, changes in the national or international economic scene. Has the Bureau's research program remained reasonably relevant in a world of rapid economic change? To some extent, of course, one can legitimately argue that economic research does not have to be immediately relevant or policy-oriented, particularly when it is concerned with

the development of basic quantitative measures, which has been the traditional National Bureau focus. Nevertheless, some linkages should be discernible between events in the world outside and shifts in research priorities in institutions such as the National Bureau.

What were the major economic events of 1971? Certainly, it was a year that saw many innovations and changes in U.S. economic institutions and policies. There was the introduction of wage and price controls for the first time in peacetime. There was devaluation of the dollar and the ending, at least for the time being, of the linkage of world currencies to gold. There was the attainment, for better or worse, of the largest federal budget deficit in the U.S. since World War II and the accompanying announcement, in effect, that pump-priming was no longer a partisan political issue. There seemed to be increasing acceptance of the notion that conventional ways of providing welfare assistance in the United States were breaking down and must be replaced by simpler, more equitable methods. Consumerism continued to gain substantial political influence, and the view that business must be socially as well as economically responsible has received increased support. Finally, we have seen a limited, but nevertheless clear shift in public priorities away from aerospace and defense and toward environmental and other concerns with the quality of life.

The events just listed have all received considerable front page attention during the past

year. They have also received a good deal of attention in Bureau research, both past and prospective, as evidenced by the staff progress reports which constitute the bulk of this Annual Report. Of course, there are important omissions: Bureau research has not thus far delved deeply into consumerism or business social responsibilities. This is regrettable but may be excusable because of the Bureau's limited financial and human resources. Furthermore, others may be better equipped than the Bureau to deal with these issues. And we have become involved during the past year at least tangentially in some of these problems. In particular, one can point to Henry Grabowski's work on the relation of advertising to the research and development process, and Michael Gort's studies of diversification and conglomerate activities.

Subject to that qualification, we might conclude that the Bureau's research has been reasonably relevant and timely. But how confident should we be in that conclusion? After all, it might well be argued that most of the topics mentioned have been quite obviously "ripe" for policy and research initiatives for some time. Even a casual reader of the newspapers of the 1960's could have foretold or identified the potential importance of most of these topics! Or so it seems in retrospect.

Accordingly, a stricter test may be in order. Specifically, were there certain events of quite considerable long-run importance for our economy and society which did not receive as much popular attention but which Bureau research should have anticipated? I suspect that there were. One, I would suggest, was the continuing evidence of decay in our central cities. Specifically, it was during the past year that the public first became fully aware of the extent to which central city population densities were declining and, more worrisome, of the accompanying abandonment of housing stock and neighborhoods that has been occurring on a systematically wider scale in the cores of our cities.

Another event that did not make too many front pages (but has increasingly done so since I first drafted these comments) was the continued decline in the U.S. birth rate. This event may in the long run prove to be the most economically and socially significant development

of the year. Its significance resides in many considerations, not least simply because it went against the accepted demographic expectations. A decline in births occurred in 1971 in spite of the fact that the age distribution of the U.S. population was such that total births should have increased. Thus, if even 1970's historically rather low birth rate had prevailed in 1971, about 400,000 more children would have been born in 1971, in addition to the 3.6 million or so who were. Actually, the crude birth rate—the number of births per thousand people—was near a record low for the nation in 1971.

Does Bureau research relate at all to these significant but less well-advertised phenomena? Over all, I would say, our "anticipation" was reasonably good. Let me review the record in these two areas, first considering our work in demography and then our urban studies.

Population Studies

As just indicated, the children of the post-World War II baby boom are now in the prime child-bearing ages and if the usual demographic forces were at work there would be every reason to expect some upsurge in births at this point in U.S. history. We should at least have observed some faint echo of the postwar baby boom now, but for some reason or another we have not. It would be very surprising if the United States were to escape that "echo" entirely. But the 1971 experience suggests that any echo may be quite limited indeed. Nothing even closely approximating the substantial surge of births that occurred between 1945 and 1958 now seems likely.

There are two questions to ask about this development. First, why has it occurred? Second, what are its implications?

Several Bureau researchers—Robert Willis, Warren Sanderson, Robert Michael, Sue Ross, and Marcia Kramer—have been attempting in various ways to apply an extended and modernized theory of consumer or household behavior to the analysis of what determines the number of births a woman will have during her lifetime and the timing and spacing of these births over her life cycle. Their approach, I am sure, will strike many demographers in the other social

sciences as too narrowly economic in character, for it may seem to overextend the applicability of economic rationality. Reproductive behavior may well be among the less rational acts of humanity! Nevertheless, it is also possible to exaggerate the irrationality of such behavior. Certainly, the broad historical trend toward lower birth rates in developed economies is striking and persistent, and seems to be associated with a reduced value or benefit derivable from having more than a limited number of children as industrialization waxes and agriculture wanes.

There is, moreover, the mystery of the baby boom of 1941 through 1958, a development that interrupted the long downward trend in U.S. birth rates accompanying industrialization. The intriguing aspect of the baby boom is whether it was an aberration or something that can be systematically explained in terms of basic economic or social causes. Previous work at the Bureau, primarily by Easterlin and Kuznets, attempted to provide such systematic explanation, stressing the positive linkages between income per capita and willingness to spend on children and their needs. Current work, by Sanderson and Willis in particular, represents an effort to extend and further test the Easterlin-Kuznets hypotheses. The question is not trivial, since, among other aspects, the answer is crucial in extrapolating or estimating future population trends.

At this point in the research, however, it would probably be the better part of candor, and circumspection, to admit that we really do not know why the baby boom occurred and why there has been the recent unexpected decline in the gross birth rate—although, as economists, we may suspect that Kuznets, Easterlin, Willis, and Sanderson are all providing us with important clues and at least some partial explanations of these phenomena.¹ Whatever the explanation, the ex-

¹ In this connection, I should mention the conference on "New Economic Approaches to Fertility, Children and Population Questions," chaired by Theodore Schultz of the University of Chicago and sponsored jointly by the National Bureau of Economic Research and the Population Council on June 8-9, 1972. The papers prepared for the conference are:

Yoram Ben-Porath, "Economic Analysis of Fertility in Israel: Point and Counterpoint";

William D. Cook, "The Demand for Contraceptive Goods and Services: A Study of Low-Income Families in New Orleans";

istence of sharp fluctuations in U.S. birth rates in the last few decades leads directly into the second basic question posed above: What are the implications of such fluctuations for the performance of the economy? For example, one obvious question to ask an economist is: If lower population growth is here to stay, is this a good or a bad thing for the U.S. economy?

Again we know all too little. It is, though, not only an important question but one with many difficult but researchable aspects. Indeed, a conference was held in the New York offices of the National Bureau in November 1971, which had the goal of defining more precisely what we know, and what we still need to know, about the economic consequences of birth-rate fluctuations. The conference was organized and sponsored by the Commission on Population Growth and the American Future, and the Bureau was host for the occasion.²

At the conference, there was fairly general agreement that slower population growth almost surely would allow real income per capita to increase faster than otherwise. Specifically, if slower population growth were to continue for the rest of the century, we could expect U.S. income per capita to be approximately 10 to 15 per cent higher by the end of the century than otherwise, all else being equal.

The reasoning behind these projections is straightforward. With slower population growth people of working age will constitute a larger fraction of the population. Possibly, too, with fewer children more women will participate in

Dennis De Tray, "Child Quality and The Demand for Children";

Bruce Gardner, "Economics of the Size of Rural Families";

Reuben Gronau, "The Effect of Children on the Housewife's Value of Time";

Robert T. Michael, "Education and the Derived Demand for Children";

T. Paul Schultz, "Disequilibrium and Variation in Birth Rates Over Space and Time: A Study of Taiwan";

Robert J. Willis, "A New Approach to the Economic Theory of Fertility Behavior."

These papers are to appear as a supplement to the *Journal of Political Economy*.

² Papers at the conference were presented by Joseph Spengler of Duke University, Alvin Kelly of the University of Wisconsin, Harvey Liebenstein of Harvard University, and Edmund Phelps of the University of Pennsylvania; it is expected that the papers and accompanying discussion (by Stephen Enke, Edgar Hoover, Robert Dorfman and Richard Easterlin) will be published shortly by the Commission.

the labor force. This labor force participation effect is, however, conjectural. Research now being done, such as that at the Bureau by Jacob Mincer and his associates, will let us, hopefully, narrow the range of uncertainty on this.

With a larger proportion of the population of working age, and perhaps a larger fraction of those of working age actually working, per capita income almost certainly should increase. To be more precise, slower population growth should bring a decline in the dependency ratio of our population; that is, the number of persons under age 18 or over 64 as a fraction of those within those age limits. In 1970 this dependency ratio was 78 per cent for the United States; that is, for every ten persons of working age (18 to 64), there were about eight persons either at or above what we usually consider to be the retirement age or under 18 and therefore assumed to be in school. If the U.S. family size were to drop to a two-child average, which, on the basis of recent birth rates, does not seem too unlikely an expectation, the dependency ratio would decline to 61 per cent by the year 2000. Furthermore, it should be noted that, of the total number of young and old persons entering into this dependency ratio, the proportion accounted for by people 65 or over would rise sharply: from 22 per cent or so today to almost 31 per cent by the year 2000 if we have two-child families.

Obviously, too, the potential social and economic costs of having those 65 and over participate in the labor force are likely to be considerably less than to have those under 18 do so. Thus, the potential increase in per capita income could well be understated by simply looking at the gross changes in the dependency ratios. Again, however, we encounter the fact that we know too little, this time about what determines the labor force participation of the aged. In particular, we have only limited ideas of how the aged might respond to changes in labor market conditions, health care, social security rules and benefits, longer vacations, and other economic and social considerations that might logically be expected to condition their decisions to remain in or remove themselves from the labor force.

We also do not have precise knowledge of how the basic economic aggregates might respond to slower population growth. For example,

it can be cogently argued—as indeed it has been by many economists—that the somewhat older labor force and population induced by slower population growth would suggest an increase in the savings rate. Such an increase, in fact, is exactly what one would expect on the basis of life-cycle hypotheses about consumer behavior. Certainly, it is true that the bulk of saving in our society seems to be done by those in the later years of their working lives, while dissaving is disproportionately done either by the retired or by those in the early stages of their working careers, corresponding to the ages of family formation and related consumer capital accumulation.³ *Ceteris paribus*, a higher savings rate should depress the marginal returns from capital (or investment) and therefore might also shift income distribution in favor of wages and salaries; this, in turn, might also argue that slower population growth would induce some further equalization of the income distribution over time. However, *ceteris paribus* is, as usual, a very large assumption. For an open economy like the United States, which is also increasingly involved in international trade, this is particularly true. Moreover, our ignorance about the basic character of international capital flows—we are only now beginning to have some quantitative knowledge of their nature and scope on the basis of previous research by the National Bureau and others—really prevents asserting with any confidence what the ultimate effects might be. Furthermore, we really do not have the detailed knowledge of how the structure of the U.S. economy itself might change; in particular, how its capital and financial requirements might be altered by the changes in consumer and other behavior resulting from the higher personal incomes and older population that would accompany slower population growth.

Before bemoaning too extensively our lack of knowledge of the longer-run implications of population fluctuations, it is perhaps worth observing that we know remarkably little as well about the short-run or more immediate consequences. For example, slower population growth may imply some equalization of income distribu-

³ See the research reported in Part II by Gilbert Ghez and Gary Becker on a life-cycle hypothesis of consumer behavior.

tion even independently of the savings and investment effects just mentioned. We do know, for example, that more unwanted births appear to have occurred historically in the United States among poor families. Thus, the reduction in family size from slower population growth might be expected to be greater for these lower-income families. In the later 1960's, in fact, the birth rate for poorer women, that is in families with incomes of less than \$5,000 per year, declined by over 15 per cent more than for the rest of our society. The poor, of course, still have a higher birth rate than the middle classes, but all the recent trends suggest that this discrepancy is disappearing, and rather more rapidly than one might expect. Accordingly, even if family or household incomes do not go up relatively more rapidly for poor families in the future—though, as just outlined, there are reasons for suspecting that they may—the per capita income available to members of lower-income families may rise relatively because their families could shrink rather more rapidly in size than middle-income families.

It would also be desirable to have better information about how changes in the age composition of population affect absorption into the labor force. Much or most of our present unemployment, for example, is due to a sharp rise in unemployment of 16- to 24-year olds, who are now a large and increasing proportion of our society because of the postwar baby boom. Slower population growth, if it should persist, would imply a relatively smaller flow of young people into the labor force, and this, in turn, could raise the relative wages of young versus older workers and simplify the absorption of younger people into the economy. On the other hand, an increase in the relative numbers of older people, coupled with stagnation in the total number of workers, could make promotions more difficult later in the life cycle. Again, certain Bureau research provides insight into these problems, e.g., the labor market studies done in recent years under the direction of Finis Welch and Jacob Mincer. Welch's work, suggesting that minimum wage laws may make teenage unemployment more prevalent, would seem particularly pertinent.

Population fluctuations may also exacerbate

or ease other problems of our society, problems generally regarded as not being economic in their origins. For example, much attention has been devoted to the observed surge in criminal activity in the United States during the 1960's. It should not be forgotten, however, that over half of all crimes tend to be committed by people under 25 years of age—and it was that very group which was growing in relative numbers in our population during the 1960's. Much of the increased crime of the 1960's was accounted for, in fact, by sharp increases in crimes that are either associated with teenagers or, by definition, are teenage crimes, such as auto theft, vandalism, violation of minimum age laws for liquor consumption, drug violations, runaways, and curfew violations. Even on very conservative assumptions, and confining attention strictly to so-called serious crimes, approximately 50 per cent of the total increase in such crime during the decade of the 1960's can be attributed either to the increase in total population or to an increase in the proportion of younger people in the crime-prone age brackets. In addition, it should be noted that high and rising teenage unemployment throughout the 1960's, particularly for teenage males in minority groups, may have made crime relatively more attractive as an economic opportunity. That is, there is perhaps an interaction among rising numbers of teenagers, difficulty in absorbing them into the labor force, their rising unemployment rates, and the observation of increased crime in our society.

Some clues to such interactions and behavioral relationships can be discerned, in fact, in various pieces of Bureau research. Isaac Ehrlich, William Landes, and Gary Becker have devoted much of their Bureau research and attention to determining "the supply of criminal activity." The central hypothesis is that one should expect a definite positive relationship between the rate of crime (in a state or community or time period) and the benefits from crime, and a negative relationship between the rate of crime and the costs associated with being caught in criminal activity. As he reports below, Ehrlich has developed some highly provocative and interesting empirical evidence in support of this hypothesis. Perhaps his finding that will be most surprising

to (and disputed by!) many observers is that, once one controls for other variables that might be expected to influence the supply of criminal activity, a negative relationship may be discernible between the incidence of murders and the imposition of the death penalty. In short, Ehrlich is inclined to the view, on the basis of his research so far, that the death penalty reduces the incidence of murder. Of course, even if one accepted Ehrlich's empirical findings, one might still be opposed to the death penalty on other grounds.

On such an important issue, moreover, the jury should perhaps remain out, at least for now. And well it might, for we really do not know as much as we should like about these and other social phenomena. It is nevertheless striking that much of the Bureau's research does provide us with at least some limited understanding of these issues.

Urban and Regional Studies

The problems of urban and regional development are not, of course, unrelated to the demographic questions just discussed. Americans have been and continue to be a highly mobile people. The fact remains, moreover, that differential rates of natural increase among different sections and groups in the country account for much of the evolving pattern of population distribution. Above all, an understanding of differential rates of natural increase is at least one key to understanding potential sources of migration.

Migration, of course, continues to be a major force modifying the distribution of population across this continent. Specifically, three main migration patterns can be discerned at present: the move from city centers to suburbs; the move from one urban center to another; and the long-standing rural to urban migration.

The National Bureau's urban and regional studies have been very much concerned with trying to better understand and model these basic migration patterns. We have particularly emphasized those from city center to suburb and from one urban center to another. A somewhat lesser emphasis on rural-to-urban migration seemed justified on the simple grounds that, while rural rates of natural increase still tend to

be higher than those in urban areas, the percentage of rural residents is declining; accordingly, the proportional impact of rural-to-urban migration must also diminish. That is, with over 70 per cent of Americans now living in areas officially classified as metropolitan, and only 5 per cent or so living on farms, migrations between cities and within cities must be increasingly important in shaping the patterns of U.S. population distribution.

The Bureau's initial approach to understanding both intrametropolitan and intermetropolitan migration patterns has been to emphasize the role of industrial location decisions. The underlying assumption (the first of two basic to the Bureau's research in this area) has been that the major exogenous or external force reshaping the distribution of population between and within our cities has been location decisions made by manufacturers. The location decision in this context is broadly defined to include both "natural growth," or expansion of employment at existing locations, and decline or death of employment opportunities as well. That is, the focus has been on the *total* redistribution of work opportunities in manufacturing, taken as a function not only of migration, or actual direct relocation of activities, but also of more subtle relocations effectuated through differential rates of growth and decline at different sites.

Manufacturing location decisions are not, of course, the only external forces at work reshaping cities. Quite clearly, certain other important classes of employment opportunities are almost equally as exogenous in their location characteristics (especially when considering intrametropolitan, as contrasted with intermetropolitan, location shifts). For example, one obvious exogenous change in employment opportunities that has been reshaping American cities in the last two decades has been the shift from railroad to airline for intercity public passenger transportation. Similarly, at the intercity level, the increasing importance of industries with relatively minor transportation needs for both factor inputs inbound and final product outbound seems to have provided an exogenous impetus to the growth of American cities that are climatically favored.

Neglect in Bureau research of these other, nonmanufacturing, forces at work reshaping

urban population distributions has been primarily a matter of limited resources. Indeed, we hope to investigate some of these other factors in the near future if funds do become available. However, as a first priority it seemed best, and still does, to emphasize the paramount role of manufacturing relocation.

The second major assumption involved in the National Bureau's studies of urban and regional location and migration patterns has been that workplace location is an important determinant of residential choice. That is, if one were to attempt to predict the residential choice made by a household, the one fact one would want to know above all others would be where the head of that household worked. But the Bureau's research on housing demand has also attempted to estimate the influence of other determinants of housing-site choices, such as family income, family composition, relative prices of different housing packages at different locations within metropolitan areas, the effects of public goods and other amenities, etc. Furthermore, and most importantly, the Bureau's research has broken new ground in attempting to understand the role of racial segregation in determining the housing choices made by both minority and nonminority groups. Research on these questions has been undertaken by Mahlon Straszheim and by John Kain and John Quigley, and their findings will be published soon by the Bureau.

Another important innovation in National Bureau urban studies has been to stress the role of housing supply, and its determinants, in influencing urban development patterns. The underlying notion has been that the stock of housing is not fixed but is indeed amenable to considerable modification and augmentation, even in the short run. By emphasizing the supply characteristics, Bureau researchers hope, among other objectives, to achieve further and deeper understanding of the processes by which housing abandonments occur. The unfortunate fact is that, with a few exceptions, supply adaptation, as differentiated from supply augmentation, has been relatively neglected in past housing studies. Of course, a full understanding of housing markets really requires interaction of demand and supply effects; achievement of a more realistic modeling of such interactions is a major

goal, in fact, of the National Bureau's Urban Simulation Model (as described in progress reports in this volume and in John Kain's introductory essay in last year's Annual Report).

Other feedbacks conditioning urban development also deserve consideration. For example, while it may be a useful first approximation to assume that many workplace locations, particularly those in manufacturing, are largely independent of residential location decisions, such an assumption is clearly not totally or strictly true. Specifically, certain kinds of industries and employment opportunities are located with labor availability and supply characteristics very much in mind. While Bureau research, and the Bureau Urban Simulation Model, have thus far largely minimized these interactions, in the future we hope to introduce them.

Obviously, there is much about urban and regional development that we either do not understand or only understand to a very limited extent. For regions, for example, we do know that there is some relationship between the scale of a conurbation and the extent to which it tends to perform functions for itself (that is, the extent to which it has grown or can grow by so-called import substitution). We really do *not* know very much, though, about the actual quantitative dimensions of the process. Similarly, we are only beginning to have the crudest sort of notion of why different industries develop different location preferences and choices, which manifest themselves in different clustering tendencies. At the intrametropolitan level, Bureau research by Robert Leone, Raymond Struyk and Franklin James (shortly to be published) will do much to further our basic empirical understanding of the dimensions and causal factors involved. At the interregional level, we still have more folklore (e.g., about the relative influence of differential tax structures and labor market characteristics) than hard facts about the determinants of industrial location decisions; here again, it is our hope that certain research now in process (such as that by Roger Schmenner and by Robert Leone and Royce Ginn) will at least eliminate some of the major deficiencies in our knowledge. Nevertheless, understanding of the basic decision processes by which industries decide to relocate and through which individuals adapt their resi-

dential location to workplace locations—not to mention the ways in which workplace locations adapt to changing residential patterns—remains very crude and primitive. The Bureau's work will make important, but still marginal, extensions on previous work in the field.

Conclusion

Where do all these new activities and research interests lead in the long-run development of the Bureau's program? Is there any coherence or theme to these developments?

I am not sure how one should answer. I would argue, though, that the complementarity between the different pieces of research, as I have tried to demonstrate in these remarks, may be a good deal greater than one might at first realize. It is striking how various pieces of seemingly unrelated research really do complement one another in terms of developing a somewhat more comprehensive understanding of certain basic problems with which our society is now concerned.

Indeed, the complementarity in the Bureau's research program really goes well beyond what

I have observed in these brief notes. For example, the work on medical economics helps, and is helped, by the population studies, labor force participation investigations, and the evaluation being done at the Bureau of educational investments. Similarly, the attempt at integrating time budgets or constraints into consumption theory could provide insight for many Bureau research projects. Moreover, in both medical economics and the study of nonmarket time allocation (which could prove the key to broadening the welfare content of some economic measures), the Bureau's record of anticipating policy concerns has been demonstrably good. In all of this, one can discern a desire to improve the precision of economic measures and to extend these measures into gauging social as well as narrowly or purely economic performance.

In terms of the development of the profession as such, one can also discern certain unifying themes in the Bureau's work. In essence, much of our new activity betokens the development of a new micro economics, which is concerned with applying the tools of economics to a broader set of society's problems—problems that are social as well as economic.

THE NBER'S COMPUTER RESEARCH CENTER FOR ECONOMICS AND MANAGEMENT SCIENCE

EDWIN KUH

The social sciences, particularly economics and management science, have been hampered by their disorganized use of computer capabilities. Massive strides in computer hardware and operating systems were not accompanied by equivalent advances in applications software, though here and there good programs were created and used. Until recently, computer usage in the social sciences was still in the "do it yourself" phase, where relatively isolated groups of individuals wrote programs to suit their particular needs. This has resulted in the proliferation of small, restricted programs that were too inflexible to adapt to the needs of other users or even to the changing needs of the authors themselves. At the same time, methods in computer science that could greatly increase the scope and availability of computer programs were all but ignored by economists and management scientists.

In response to this situation, five years ago the TROLL research project at MIT began to bridge the gap between computer systems potential and econometric practice. The product of that research, TROLL/1, is a large interactive system that is just now becoming available to practicing economists. This system has sophisticated data handling and graphics capabilities, as well as a broad set of estimation and simulation techniques. It has convincingly demonstrated the feasibility and power of systems programming as applied to quantitative economic research.

Given the enormous impact of the computer on the economics profession and the concerns of the NBER with applied economics and its methodology, it was natural for the NBER to propose to the National Science Foundation that a computer research center be established to apply large-scale systems programming to the more intractable research needs in quantitative economics and management science. At the Center's inception, John Meyer remarked that:

... the Bureau has also undertaken the establishment of a Center to explore in depth the

computer's role in economic research and management. *The creation of this Computer Research Center in Cambridge, Massachusetts during 1970-71 stands in all probability as the single most important event to have occurred within the Bureau during the last decade.* The new Center's research program, as it has emerged from plans formulated over the past summer, will reinforce what is best in the Bureau's empirical tradition. One of the Center's first priorities will be to apply or, more accurately, adapt to economics the tools of a newly emerging field in statistics called data analysis. As its name implies, data analysis is concerned with how the intuitive feel or understanding of data can be systematically acquired and applied to empirical research problems. Thus, much of the early research to be conducted at the Center will focus on improving visual displays in the manipulation of data. The objective will be to bring the economic researcher back into closer contact with his data, something that the computer revolution has unfortunately too often diluted in economic research. In essence, data analysis greatly improves the analytic content of data investigation and manipulation. The nomenclature is different and the techniques often more mathematical, but the concepts would be familiar and congenial to Wesley Claire Mitchell.

In short, the new Computer Center is concerned with some of the most fundamental and also practical aspects of modern empirical research in economics. Since such research is the basic occupation of the Bureau, the new Center's importance, even centrality, to the Bureau's whole program can hardly be overestimated.¹

The National Science Foundation grant began February 1, 1971, and continues for two years. However, the National Science Board has given approval for a five-year funding period, so that continued support from NSF can be anticipated with confidence. The core programming staff transferred to the Center's new quarters from the TROLL project in August 1971, when actual work at the Center commenced. The transition from work on TROLL to new activities at the Cen-

¹ J. R. Meyer, "President's Report to the Board of Directors, September 27, 1971," *NBER Newsletter*, February 28, 1972.

ter has been gradual and is now largely completed. Since TROLL was a prototype of these new activities in a number of significant respects, the completion of TROLL has provided useful insights into organizational and support activities the Center should pursue. A fundamental difference between the TROLL project and the Center is that the latter has a much greater research, as distinct from computer systems, thrust. While considerable new algorithmic research has been incorporated into TROLL, the intent was to embody econometric techniques into an interactive computer environment. Thus, most of the resources of the TROLL project went into systems programming. The Center, on the other hand, because it can capitalize on the TROLL operating system, is able to put its major efforts into research and applications programming without neglecting serious systems programming as well.

The Programming Effort at the Center

One of the Center's strong features is the combination of sophisticated researchers and a highly skilled programming staff. The latter is composed of a group of committed professionals with many years of experience in the creation of large application-oriented computer programs. In order to provide an effective computer environment, the programming staff, under the supervision of the Technical Director, Mark Eisner, is active in all aspects of software development. This development can be divided into three broad categories: the basic operating system, an application control language, and various application programs themselves. The first two categories provide the basic support which allows new computer methods and programs to be created and executed in an efficient and well-organized process. The last and by far the largest activity is the implementation of methods and techniques themselves.

Gerald Ruderman leads the systems programming group, which is currently implementing a specialized Center Operating System (COS) to take advantage of the discipline-oriented nature of the applications being developed. This operating system provides the functions of input/out-

put control, interrupt handling, and file maintenance, as well as interfacing with the computer's operating system. Much of the responsibility for implementing COS rests on our two full-time systems programmers, David Anderson and Walter Oney, both of whom have had experience with general operating systems at MIT. They will be assisted by Fred Abramson, who has had a long part-time association with TROLL and the Center.

Currently, COS is designed to run under the IBM Control Program for the 360/67. In the near future, COS will also interface with new releases of IBM's standard operating system, allowing programs produced at the Center to run on appropriately configured IBM 360 and 370 computers. The Center has also embarked on some innovative systems programming which will allow a large number of users to use programs simultaneously. This programming involves modifications to the IBM Control Program, increasing the efficiency of the 360/67 to a degree not previously attained. Another aspect of the systems programming activity is the development and implementation of procedures to maintain, debug, and test the software developed by the Center.

The second major systems programming effort will be to create an application control language. This is a specialized language which greatly facilitates the addition of new applications tasks into the system as a whole. This language will provide essential features to the applications programmers, e.g., the ability to define a command interface, the types of files they wish to create, and special communication or "common" regions. It will also allow modules to be called from within other programs and will have a facility to enable programmers and sophisticated users to create their own tasks by combining existing tasks or modules. Because of the importance of this facility, most of the senior programmers are involved in the design effort.

The primary responsibility for implementing the design will rest with Fred Ciaramaglia, who heads the programming staff; he will be assisted by Joel Lexier. Another feature of the applications programming effort is the encouragement given to dialogue between researcher and pro-

grammer. This vital communication is given the highest priority and is one of Eisner's responsibilities.

The programming effort at the Center is based on the new technology of virtual memories and interactive systems. We feel that the programs and methods developed here will provide researchers in the field with capabilities that will be valuable for many years to come. However, the programming effort itself must be viewed as a research project in the better utilization of computer resources. We think this effort will result in significant accomplishments in the area of software development.

Mathematical Programming

Present knowledge of mathematical programming is so sophisticated that future progress requires an intimate relationship between the development of mathematical techniques and their implementation in efficient computer systems. The Center has begun assembling an experienced staff of mathematical programming systems scientists, maintaining this staff full-time, and providing the research support necessary to produce advanced systems; i.e., the working environment, supporting personnel, and availability of large blocks of computing time on a large-scale machine.

An excellent start in this area is provided by William Orchard-Hays, who has been at the Center since January 1972. Over the past twenty years he has been responsible for the design and implementation of several large-scale mathematical programming systems for IBM, Honeywell, and Control Data Corporation, and he has also worked for the Rand Corporation and several management consulting firms. Jeremy Shapiro of MIT, an authority on integer programming, will be on leave at the Center in 1972-73, working with Orchard-Hays. The months from January to June will be spent designing the new mathematical programming system; development will begin during the summer. William Northup will assist in the development of integer programming algorithms. Several more mathematical programming experts and computer programmers will join the Center to help implement this large, complicated effort.

A number of mathematical programming systems have been developed in the past, some of considerable power. It has become clear, however, that the power of mathematical programming systems is not always usable in the context of a total project, either because of system conflicts or because of financial and policy problems. Furthermore, none of the present large mathematical programming systems can be used in a truly interactive sense, that is, from a remote console. It seems desirable to create a mathematical programming system which can be used in interactive or batch mode, or in both modes, and which can be made readily available to research and academic groups. Such a system should have the power of existing systems with respect to such features as problem size and algorithmic repertoire, but should be much more flexible, more standardized in conventions, and more adaptable to research in such iterative schemes as mixed integer and nonlinear programming.

Data Analysis

Data analysis reorients empirical research methods by integrating statistical theory more closely with the realities of applied problems. An emphasis on an initial visual and parametric exploration of the data series is one central aspect of data analysis. This initial exploration helps clarify distribution characteristics, e.g., outliers, skewness, and multimodality. The Center has adapted the capabilities of SNAP-IEDA, a data analysis program prepared at Princeton by David Hoaglin under the direction of John Tukey. This interactive adaptation is being used by Hoaglin and Roy Welsch in courses that they are currently teaching at Harvard and MIT, respectively. The program contains various graphical displays of sample information, a number of functions (including seven probability distributions and Monte Carlo sampling from each), and various data transformations.

The Tukey approach can be beneficially modified in two directions. First, data analysis lends itself naturally to interactive computer programming, and we intend to move strongly in that direction. It will be particularly useful to have interactive graphic capabilities, enabling an in-

investigator to delete or add points, sketch lines or curves summarizing data configurations, etc. The second aspect open to improvement is the emphasis that the Tukey approach places on hand processing of a data set. It should be a relatively simple matter to expedite the data analysis process by computerizing a number of steps. Richard Hill, who has programmed SNAP-IEDA functions onto the Center's system, will be heavily involved in the programming aspect of data analysis. He will be assisted by Helge Bjaaland, who has primary responsibility for the graphics applications at the Center.

Beginning July 1, 1972, Paul Holland of the Harvard University Statistics Department will join the Center on a full-time basis. He will have major responsibility for the subsequent development of research in data analysis. Hoaglin, Welsch, and I will have a continuing and active research interest in this and other aspects of data analysis.

Since real-world data often violate convenient assumptions about the error processes used in the mathematically more tractable statistical models, the development of robust estimators is another integral part of data analysis. Under Tukey's leadership, a group of statisticians at Princeton University has made an excellent analysis of robust estimators of the mean, where the frequency distribution assumes a variety of non-normal forms. Econometricians could benefit greatly if these tools were readily available. Some work is now going on in the area of robust estimation of regression models, and the Center will evaluate alternative approaches in promoting research and subsequent dissemination.

One problem that arises frequently in applied econometric work is the stability of the underlying regression regime. Regression coefficients often change from one period to the next. When the break-points in the regime must be estimated along with the different sets of regression coefficients, the problem becomes both more realistic and more difficult. Several approaches have been proposed by Richard Quandt and James Durbin, among others. David Belsley of Boston College will work on this and other data analysis problems at the Center during the coming summer.

Cluster analysis is a promising nonparametric

way to study multivariate data. Cluster analysis can be thought of as a first cousin to principal components or factor analysis. There are a number of significantly different algorithms for clustering. The Center plans to study these alternatives and to determine to what extent these methods can illuminate problems in economics and management science.

Estimation of Equation Systems

Simultaneous-equation estimation theory has produced literally dozens of estimators, all having similar asymptotic properties. Existing comparative studies of alternate estimators provide little guidance on which ones are best. From among the plethora of estimators, combinations of two major principles provide four major options: least squares in its limited or full information variant (two- and three-stage least squares, respectively); and maximum likelihood, either in its limited or full information formulation (designated as LIML and FIML). Most practicing econometricians prefer two-stage least squares on the grounds of computational simplicity, since full information methods (even three-stage least squares) require sophisticated computer programming. FIML is far and away the most complicated estimation procedure, since it is nonlinear in the coefficients to be estimated even when the structural equations are linear. Thus, few full information estimation programs are available. Where they have been implemented, the choices among them are unclear.

Under the joint direction of Gregory Chow of Princeton University and J. Phillip Cooper of the University of Chicago, the Center has started a small-scale project to create programs for a half-dozen full information estimators. The primary programming responsibility will be Jonathan Shane's, who helped implement the single-equation regression capability in TROLL. The Center can undertake this project at moderate cost because particular modules in TROLL, as well as the programming skills to extend them, are already available. Further, the concurrent work on mathematical programming is beneficial, since both tasks require the optimization of functions that are nonlinear or discontinuous in the parameters of large simultaneous systems

of equations. Repeated, accurate inversion of large matrices is also of central importance to both.

Spectral Analysis

Spectral analysis can be viewed as one sort of data analytic device that should be available in a complete set of estimation tools. Robert Engle of MIT has designed a set of modules for this analytic process. Because of the existing TROLL system and the simplicity of the modules themselves, these have proven to be easily implemented. Two extensions of the basic program will be completed by summer, both of which utilize spectral analysis in the more familiar regression context. Of greatest novelty and potential importance is the use of spectral analysis to decompose a time series into components of different frequency. A fraction of the original series, purged of certain components, can then be used as most germane to the subject at hand. For instance, Engle and Duncan Foley, also of MIT, are studying aggregate investment behavior where only the low-frequency component of stock prices is a strategic variable. Engle has developed the estimator and its sampling properties. A second regression application is generalized least squares, where the spectrum from regression-equation residuals (based only on exogenous right-hand-side variables) provides the basis for generalized least squares for any linear autoregressive or moving average process, a generality missing in most standard first- or second-order autoregressive transformations.

Systems Dissemination and Assurance

The support staff at the Center, led by John Kirsch, is responsible for systems dissemination and assurance. In this context, dissemination means recruiting and training users of the Center's systems and providing appropriate documentation. Also implicit in the dissemination activity is the gathering and channeling of feedback from users to systems designers and programmers. The systems-assurance function involves coordinating the release of system revisions with appropriate testing and documenta-

tion updating.

The focus of our initial efforts in these areas has been TROLL. TROLL's operating system is a prototype of the Center Operating System (COS) that is now being developed; the relationship is especially close in the case of user-visible support facilities, such as the shared file system, generalized graphics facilities, and on-line user prompting and documentation. Further, TROLL's current application subsystems—regression, simulation, and a basic data analysis/transformation facility—will be transported into the COS environment for use in parallel with the new research subsystems developed at the Center. In general, then, TROLL has given the support staff a good preview of the patterns of system-user-Center interaction which will be encountered over the life of the Center.

Our priorities and progress to date have been shaped by three major problems of an essentially start-up nature. First, there was a large backlog of TROLL user documentation to be written. Second, although two support-staff members were incumbents of the old MIT TROLL project, other people had to be recruited and trained to complement their efforts. Third, systems and procedures for maintenance-related problems (e.g., technical documentation, bug reporting, system testing) had to be developed.

In the user-documentation area, a researcher's overview of TROLL, a brief primer, and a lengthy tutorial guide to the system's capabilities have been written. A system reference manual for TROLL will be published in installments. Several levels of on-line documentation (i.e., documentation available to the user while working with the system) are being created, including both concise command-format summaries and fuller narrative explanations of each command.

Rapid completion of an initial version of the Center's data-analysis package allowed us to experiment with a collaborative approach to user documentation of new software. In this approach, support-staff members served as editorial middle-men between programmers, who wrote initial low-level user specifications, and researchers, who, having designed the new routines, were able to draft explanations of their application to specified problems.

In our dissemination work, we have experi-

mented with a variety of training, consultation, and promotional methods. Walt Maling, assisted by other support-staff members, conducted a series of six half-day introductory seminars on TROLL at various institutions throughout New England. These were attended by researchers from about twenty of the smaller New England colleges and universities. Intensive workshops, from two days to two weeks in length, have been presented, or are being planned, for major user communities, including MIT, New Haven (Yale/NBER), New York (NBER), and Washington. These more or less formal educa-

tional efforts are complemented by direct, on-going consultation with individual users of TROLL. In support of the dissemination effort, articles about COS/TROLL and the Center were placed in the Bureau's *Annals of Economic and Social Measurement*, in MIT's *Technology Review*, and in *Computerworld*.²

² In addition to the members of the support staff mentioned here, special note should be made of the work done by Nancy Burrows, Darhsiung Chang, Robert Perron, and Wayne Zafft.

The smooth operation of the Center is largely due to the good efforts of Warren Lackstrom, who, with his assistant Anne Koteen, has removed the burden of business detail from the professional staff.

ANNALS OF ECONOMIC AND SOCIAL MEASUREMENT

SANFORD V. BERG

1972 saw the introduction of a new form of publication by the National Bureau: the *Annals of Economic and Social Measurement*, a quarterly journal focusing on computers, information retrieval, and research methodology. One of the principal activities of the Bureau over the past half century has been economic and social measurement. The computer has created new possibilities for analytical and methodological advances in this area, and the start of several new NBER activities, as well as the desirability of rapid information dissemination required the journal format to keep the NBER at the forefront in linking advanced computer technology to empirical research. The statement of purpose carried in the *Annals* incorporates this reasoning:

The purpose of the *Annals of Economic and Social Measurement* is to promote the exchange of ideas in quantitative research. The journal will contain articles generated in the research program of the National Bureau of Economic Research or relevant to this program, mainly but not solely dealing with data generation, computer applications, and methodological problems. Participants in workshops held by the NBER's Conference on the Computer in Economic and Social Research and researchers affiliated with the NBER's Computer Research Center for Economics and Management Science will be encouraged to contribute papers.

We hope that the *Annals* will serve a catalytic role in improving techniques for economic and social measurement. Although research methodology will be stressed, descriptions of computer programs, information retrieval techniques, and data sets will also be published. Such an emphasis means that scientists can benefit from work in fields outside their immediate range of research. The objective is to provide rapid and wide dissemination of advances in the state of the art—resulting, it is hoped, in more effective use of the computer in quantitative analysis.

Our aim is to produce a publication which can be of benefit to both the generalist and the specialist. By bringing insights to the nontechnical researcher, the journal should provide a significant service to several related disciplines. Furthermore, it provides a forum for specialists to address one another regarding current develop-

ments and serves as a research archive for retrospective searching.

Examples of the types of articles published this year should give an idea of how both macro and micro models have been examined in the *Annals*. Lags, nonlinearities, stochastic shocks, and other elements have entered our models partly because of the capabilities of the computer. However, evaluating the performance of large-scale econometric models is not a simple matter; the third issue of the *Annals* includes a multiauthored report on this problem, generated by the NSF-NBER Seminar Series in Econometrics and Mathematical Economics. Similarly, many researchers collaborated in the "Micro-analytic Simulation Model of Household Behavior," developed at the Urban Institute and reported in the second issue of the *Annals*.

Besides articles which are the outgrowth of NBER conferences or sponsored research, the *Annals* has been publishing timely announcements of developments in the areas it surveys. We have directed attention to a number of activities and evolving institutions with a view toward reducing duplication of effort and informing those who wish to keep abreast of developments.

The emphasis on data sets and information retrieval reflects the NBER's interest in such topics since its beginning. F. Thomas Juster, Harold Watts, and others have contributed articles to the *Annals* focusing on microdata, i.e., the problems and possibilities which individual observations present. Researchers can benefit from lessons learned by those on the research frontier, and we intend to continue to report on data sets, match/merge techniques, and similar topics. Instead of book reviews, we have inaugurated a series of data set reviews. The first covered the Dun & Bradstreet data base on manufacturing establishments, and described the strengths and limitations of the data, using a workplace location study to focus on issues of comparability and coverage.

Charlotte Boschan's "NBER Time Series Data Bank" is another example of a data set review.

in that article, she discusses the format, technology, and economics of current operations, including file organization, software, operating procedures, directories, and on-line documentation. Such information should prove useful to those concerned with the technology of data retrieval as well as to the users of data banks. Another type of information is described by Richard and Nancy Ruggles in an *Annals* article resulting from a workshop sponsored by the NBER Computer Conference; they describe computerized bibliographic systems and other research aids made possible through new technologies.

The changing character of quantitative research is reflected in new approaches to social and economic measurement. The identification of exogenous variables, the handling of complex adjustment processes, Bayesian applications, and other topics are discussed in terms of substantive as well as methodological issues, with the emphasis on the latter. Later, we expect to

publish the results of work carried out in conjunction with the NBER Computer Research Center for Economics and Management Science.

Many individuals have contributed their time and energy to getting this new venture off the ground. Neville Beharie has served ably as assistant editor. Phillip Cagan, Solomon Fabricant, John Meyer, Jacob Mincer, M. I. Nadiri, and Christopher Sims, as members of the editorial board, have all provided guidance and helped to insure that the quality of articles is in the best traditions of the NBER.

It is the hope of the board that the articles published in the new journal will inform, instruct, and motivate researchers in economics, statistics, and management science, and that they will convey a sense of the exciting possibilities for future research offered by intellectual and technological advances in economics and social measurement.