Replication in Empirical Economics: The *Journal of Money, Credit and Banking Project*

By WILLIAM G. DEWALD, JERRY G. THURSBY, AND RICHARD G. ANDERSON*

This paper examines the role of replication in empirical economic research. It presents the findings of a two-year study that collected programs and data from authors and attempted to replicate their published results. Our research provides new and important information about the extent and causes of failures to replicate published results in economics. Our findings suggest that inadvertent errors in published empirical articles are a commonplace rather than a rare occurrence.

The confirmation of research findings through replication by other researchers is an essential part of scientific methodology. William Broad and Nicholas Wade in *Betrayers of Truth* (1983) present examples wherein the inability of other researchers to replicate published scientific findings revealed both inadvertent errors and outright fraud. Replications in the physical and social sciences are attempted infrequently, however. Thomas Kuhn (1970) emphasized that replication—however valuable in the search for knowledge—does not fit within the "puzzle-solving" paradigm which defines the reward structure in scientific research. Scientific and professional laurels are not awarded for replicating another scientist's findings. Further, a researcher undertaking a replication may be viewed as lacking imagination and creativity, or of being unable to allocate his time wisely among competing research projects. In addition, replications may be interpreted as reflecting a lack of trust in another scientist's integrity and ability, as a critique of the scientist's findings, or as a personal dispute between researchers. Finally, ambiguities and/or errors in the documentation of the original research may leave the researcher unable to distinguish between errors in the replication and in the original study. Months of effort may yield the replicator only inconclusive results regarding the validity of the original study, and thus no foundation for his future research in the area. These circumstances nurture a natural reluctance to undertake replication studies.

In July 1982, the *Journal of Money, Credit and Banking*, with financial support from the National Science Foundation, embarked upon the *JMCB Data Storage and Evaluation Project*. As part of the *Project*, the *JMCB* adopted an editorial policy of requesting from authors the programs and data used in their articles and making these programs and data available to other researchers on request. In a second part of the *Project*, we attempted replication of published results for a number of the submitted data sets. Our findings suggest that inadvertent errors in

*Dewald is Senior Economist, Bureau of Economic and Business Affairs, U.S. Department of State, Washington, D.C. 20520. Thursby and Anderson are Associate and Assistant Professors, respectively, Department of Economics, The Ohio State University, Columbus, OH 43210. We extend our thanks to the *Journal of Money, Credit and Banking* and to the present editors of the *JMCB* for their cooperation and decision to continue to request that authors submit data along with papers for review. We thank the National Science Foundation for financial support under contract SES-8112800. We extend special thanks to the authors who responded to our requests for programs and data, many of whom spent significant amounts of time and resources compiling materials for this project. We thank Hashem Dezbakhsh, Roger Lagunoff, and Joseph Hohman for research assistance, and Jeanette White, the *JMCB* secretary, for supervising the receipt and distribution of data sets. We thank Ed Kuh and MIT's Center for Computational Research in Economics and Management Science for loaning us the TROLL computer program. We also thank Benjamin Friedman, Lawrence Goldberg, Edward J. Kane, Thomas Mayer, Daniel Newlon, Edward J. Ray, Anthony Saunders, George Stigler, Stephen Stigler, Roger Waud, and Geoffrey Woglom for their comments and assistance. Responsibility for errors remains ours.

published empirical articles are a commonplace rather than a rare occurrence. While correction of the errors did not affect the authors' conclusions in most studies, the errors make independent replication impossible unless the replicator errs in precisely the same way.

In one crucial aspect, replications in empirical economics are simpler than in the experimental sciences: given the researcher's computer programs and data set, calculations may be repeated. The required programs and data are rarely available for replication, however. Many researchers employ proprietary statistical packages such as SAS, SPSS, TROLL, TSP, etc., which prohibit copying the program; replication is impossible for the individual researcher without subsidized (for example, major university) access to the same computer hardware and software. Many other researchers utilize programs which they or their research assistants have written in FORTRAN, Pascal, or other languages; interpretation and evaluation of these programs is difficult at best—and impossible at worst—without considerable skill, experience, and the cooperation of the original programmer. Dean Leimer and Selig Lesnoy (1982), for example, traced the false conclusions of Martin Feldstein (1974) to a computer programming error; we discovered similar errors in some of our replication studies. Finally, we note that some research projects employ computer programs of such enormous size and complexity as to all but guarantee that no other researcher will attempt replication of the study. The large-scale macroeconometric models such as the MPS model are members of this group. We discuss below our attempts at replication of a study based on the MPS model at Harvard University.

Similar problems arise with data. Some data are confidential, having significant proprietary value due to the difficulty and/or expense of their collection, while federal law makes other data available only for the internal use of employees of government agencies such as the Federal Reserve System. In the *JMCB Project*, many authors furnished their data even when the data had not been fully exploited in their own research. For other researchers, however, private interest prevailed and our request was either refused or ignored. We note that NSF Policy Number 754.2 *requires* that computer programs and data which have been produced with the assistance of NSF grants be made available to other researchers either by publication, duplication, or loan to the researcher. Investigators have the first right of publication, but the NSF rule requires that the programs and data be made available to others. It appears that this policy is seldom enforced and that investigators either are unaware of the policy or unafraid of the penalties for failure to comply with it.

I. The Role of Professional Journals

Professional journals disseminate authors' findings throughout the world. Our results suggest that journals take a more active role in assuring the quality of the results presented in empirical studies.[1] As editor of *Econometrica*, Ragnar Frisch argued for such a role in the first issue of that journal: "In statistical and other numerical work presented in *Econometrica* the original raw data will, as a rule, be published, unless their volume is excessive. This is important in order to stimulate criticism, control, and further studies" (1933, p. 3). Today, most economics journals except the *JMCB* do not have editorial policies which facilitate replication of published results by requesting programs and data sets from authors.

It is a matter of public record that errors exist in published empirical studies. Recent examples include Leimer and Lesnoy, cited above, and Frederick Siskind's 1977 correction of Finis Welch's 1974 minimum wage study. Our research suggests that there are many more unrecorded and undiscovered cases similar to these.

The frequency and magnitude of errors in empirical articles raise serious questions regarding the integrity of the refereeing process of professional journals. Referees are concerned primarily with methodology, the-

[1]An argument for the role of professional journals is presented by Edward Kane (1984).

oretical specification, statistical estimators, and importance of results; an author's programs, data, and calculations are typically assumed to be correct. While our findings suggest that this assumption often is unwarranted, we hesitate to suggest—due to the massive amount of time which would be required—that referees should be required to check an author's computer programs and data. Our findings suggest that the existence of a requirement that authors submit to the journal their programs and data along with each manuscript would significantly reduce the frequency and magnitude of errors. We found that the very process of authors compiling their programs and data for submission reveals to them ambiguities, errors, and oversights which otherwise would be undetected.

Our experience with authors who had not prepared programs and data for submission to the *JMCB prior to* submission of the article is indicative of the difficulties. Many could not locate the data for the article, while others had lost their programming. Even when the programs and data could be located, authors often had not kept a contemporaneous record of the progress of the research and could not reconstruct their results. In many cases—particularly in larger universities—graduate student research assistants had conducted essential parts of the research project, and after their departure it was impossible to reconstruct data sets from original sources.

In principle, the marketplace of economic research might be expected to provide a check against careless, undocumented empirical research. Since the editorial policies of professional journals had failed to address the problems of replication of published work, Edgar Feige proposed in 1975 that "...as a minimum standard, journal editors could explicitly publicize the necessity of full reporting of procedures and data..." (p. 1293). In response to Feige, the editors of the *Journal of Political Economy* wrote:

> We believe that the true remedy is resort to the powerful force of competition. We believe that journals should be prepared to accept alternative statistical tests of a hypothesis, in which either the confirmation or the contradiction of the author's statistical tests is reported. For this task to be reasonably economical, any author should be willing to provide his underlying data to other scholars (at cost). Indeed, this behavior is a requirement for responsible scholarship.
>
> [1975, p. 1295]

The editors subsequently added a new section to the journal devoted to verifications and contradictions of papers first published in the *JPE*. Invariably, this section contained papers employing either new data sets or alternative statistical techniques; little attention was paid to replication. Further, the *JPE* neither required nor facilitated making programs and data available for replication attempts.

The *JPE* experiment is a classic example of market failure. The benefits of reduced frequency and magnitude of errors in empirical articles share many of the characteristics of public goods: all who read the journal benefit from the knowledge that the research reported in its articles has been more carefully monitored by the researcher; the quantity of benefits available to any single reader is not reduced by others reading the journal; and it is difficult to induce the reader to reveal his or her true value (price) for better quality articles. A single researcher faces high costs in time and money from undertaking replication of a study and finds no ready marketplace which correctly prices the social and individual value of the good.

An editorial policy which requires the submission of programs and data to the journal has two significant advantages relative to a *laissez-faire* system wherein interested researchers must contact authors directly. First, it substantially reduces the cost borne by a researcher seeking to replicate original research. The economic self-interest of the author in satisfying the editors of the journal assures that the materials submitted to the journal are more complete and correct than what if anything might be furnished to an individual researcher. The journal provides a cost-effective clearinghouse for these materials, relieving the author of the burden of furnishing programs and data to many researchers individually. Perhaps most importantly, potential replicators avoid giving the impression of challenging an author's results by obtaining programs and data from the journal rather than from the author. Thus, these editorial policies reduce barriers-to-entry in replication and thereby facilitate the market-driven outcome suggested by the editors of the *JPE*. Second, readers of the journal benefit by knowing that the likelihood of an error in a published study has been reduced by careful preparation of the programs and data for submission to the journal, and that the referees of the article have had access to the programs and data. In this respect, the editorial policy is a form of professional collective action which solves the public goods problem by combining the values of the good to individual readers.

In recognition of the importance of data collection and construction, the *Review of Public Use Data* and the *Journal of Econometrics* have entered into an arrangement whereby authors of applied articles in the *Journal* are given preference to publish supplementary data in the *Review*. Overall, however, professional journals in economics have not adopted editorial policies to facilitate replication, and there have been few attempted replications.

II. The Response of Authors to Requests for Data

The *JMCB Project* requested programs and data from the authors of all empirical articles published during or after 1980. These requests are usefully divided into two groups. The first group consists of authors of articles published prior to the start of the *JMCB Project* in July 1982. This control group had submitted and published articles in the *JMCB* without knowledge that a subsequent request would be made by the *JMCB* for their programs and data. The second group consists of authors whose articles, beginning July 1982, were either: (*i*) accepted for publication but not yet published, or (*ii*) under review by referees. We are grateful to the many authors who supplied programs and data, thereby prospectively subjecting their research to replication. For others, the nonresponse rate is itself an important finding of the *Project*. Table 1 summarizes the responses of authors to our requests.

In the first group, 42 of 62 authors responded to our request and 22 of the authors submitted programs or data. Approximately one-third of the authors (20) never replied to our repeated requests, and an additional one-third (20) replied that they could not furnish their programs or data. The motives of the 20 authors who did not reply to our requests are not known. Much more informative are the responses of the 20 who replied but did not furnish programs and data. Two authors wrote that their data were confidential and could not be released. Fourteen wrote that they had lost or discarded their data. The others wrote that their data were readily available from published sources but did not furnish the data, leaving collection of the data to us. We report below the results of an experiment wherein we attempted to replicate one study by collecting data from published sources.

Why were 18 of these 20 authors unable to provide programs and data, some as little as six months after publication of the article? We surmise that some authors simply may not keep programs and data after completion of a research project and, in any case, that authors devote most of their effort to the completion of a publishable manuscript and little to the tedious task of compiling, rechecking, and documenting programs and data. The authors who submitted data informed us that compiling the materials which we requested was often a lengthy and expensive task. A low-cost alternative is to ignore the request for data as just another questionaire, or to reply that the data are lost, destroyed, or available from published sources. Economists recognize that optimizing behavior allocates resources to their most productive uses. Our results are not unexpected when professional rewards generally arise from the publication of articles and rarely from documentation of the research or providing the underlying materials to other researchers.

We emphasize that authors in this first group were not aware during the course of

TABLE 1—RESPONSES TO REQUESTS FOR DATA FROM AUTHORS OF EMPIRICAL PAPERS[a]

	Published before Data Requested	Accepted before Data Requested	Under Review when Data Requested
Requests	62	27	65
Responses	42	26	49
Response Rate (Percent)	66	96	75
Mean Response Time (Days)	217	125	130
Not Submitted:			
Confidential Data	2	1[b]	0
Lost or Destroyed Data	14	2	1
Data Available, But Not Sent[c]	4	2	1
Nonrespondents	20	1	16
Total Not Submitted	40	6	18
Nonsubmission Rate (Percent)	66	22	28

[a] Includes all requests made through December 1984, and excludes authors whose papers were rejected.

[b] Two data sets were partially confidential.

[c] This category includes authors who (*i*) stated that their data were available from published sources, but did not send their data; and (*ii*) authors who claimed to have their data but were unwilling to sort through their papers to find the data.

their research that the *JMCB* would subsequently request their programs and data. Several authors wrote that they easily could have supplied programs and data at the time of initial submission of the manuscript for review. Nevertheless, it is surprising that they did not retain their programs and data for a year or two after publication, not only for their own research but also, where research was supported by NSF, to satisfy its policy requiring that such information be provided to other researchers.

The responses of the second group of authors are summarized in the second and third columns of Table 1. The proportion of authors who submitted programs or data is significantly larger than the 34 percent submission rate of authors in the first group: 72 and 78 percent for papers-under-review and papers-accepted-but-not-published, respectively. The reasons for not submitting programs and data were similar to those given by the first group of authors. Two authors of accepted-but-not-published papers reported that they had already lost or destroyed their data, and one of the 27 authors in this group never replied to our repeated requests for data.

The response rate of authors whose papers were under review by referees was only 75 percent. All authors were given a minimum of six months to respond, and nonresponse was followed by a second request. While the *JMCB* has not made submission of the data a requirement for either submission or publication of a paper, it is nonetheless noteworthy that one-fourth of the authors would not even reply to a letter from the journal reviewing their manuscript for publication. We can speculate that some authors did not compile or organize their programs and data prior to submission of their manuscript and would have responded if a favorable publication decision was reached, but perhaps not. One of the authors who replied said that he had already lost or destroyed the data before a decision had been reached regarding publication of the manuscript.

III. Characteristics of the Submitted Datasets

Data are useless to another researcher unless accurately recorded and properly documented. Our goal for each submitted data set was that it be complete enough to allow an attempt at replication. We examined the first 54 submitted data sets to determine how often that goal was met. Eight, or 15 percent, were judged to have met that goal, while 14, or 26 percent, were judged incomplete. The

TABLE 2—PROBLEMS IN SUBMITTED DATA SETS

	Published before Data Requested	Accepted before Data Requested	Under Review when Data Requested
No Problems	1	3	4
Problems Identified:			
Incomplete Submission	6	3	5
Sources Cited Incorrectly	0	4	4
Sources Cited Imprecisely	11	7	10
Data Transformations Described Incompletely	3	4	1
Data Element Not Clearly Defined	2	3	2
Other	0	3	1
Problems	22	24	23
Data Sets Examined	19	14	21

problems which we encountered are summarized in Table 2. The most frequent problem was a failure to identify the sources of the data precisely. This problem was somewhat more common among data sets submitted by authors in the first group who, in some cases, had completed the research project several years earlier. Similarly, incomplete data sets also were more common with this group. Further, only 34 percent of the authors in this group were willing or able to submit any data.

The identification of individual variables was a problem in many data sets. Submitted programs and data sets often were so inadequately documented that we could not identify the variables which had been used in calculating the published empirical results. The variable names in some data sets did not match those in the published articles, some data sets contained no variable names at all, and a few data sets omitted the original data from which the author had constructed new transformed variables. In addition, some authors had discarded data on variables which they reported as having insignificant coefficient estimates in their regressions. While we attempted to resolve any ambiguity by contacting authors, usually they had sent us all available information and the ambiguity could not be resolved.

We attempted to replicate several data sets from the authors' stated original published sources. Many authors cited only general sources such as *Survey of Current Business*, *Federal Reserve Bulletin*, or *International Financial Statistics*, but did not identify the specific issues, tables, and pages from which the data had been extracted. Since government economic data may be revised several times after their initial publication, we often found ourselves unable to reconstruct data sets from such vague documentation. We present in Section V an experiment which illustrates the wide range of possible results that may be obtained in replications based on published data.

TABLE 3—CANARELLA AND GARSTON ORIGINAL AND CORRECTED RESULTS, LIKELIHOOD-RATIO TESTS OF RATIONAL EXPECTATIONS AND DEBT NEUTRALITY, REAL OUTPUT MODEL

Hypothesis Tested	Original Results	Revised Results
REH and EH Restrictions Applied to		
Money	6.246	7.014
Debt	2.302	.774
Money and Debt	8.286	8.632
SN and EH Restrictions Applied to		
Money	6.350	15.808[b]
Debt	2.794	4.274
Money and Debt	13.364[b]	20.930[b]
REH, SN and EH Restrictions Applied to		
Money	12.454	22.802[a]
Debt	4.272	4.594
Money and Debt	20.744[a]	28.888[b]

Note: *REH* = Rational expectations hypothesis; *EH* = Efficiency hypothesis; *SN* = Structural neutrality.
[a] = Significant at 5 percent level.
[b] = Significant at 1 percent level.

Time and resources did not permit replication and reconstruction of all submitted data sets. Detailed examination of a sample

TABLE 4—MAYER AND NATHAN ORIGINAL AND CORRECTED RESULTS, CONTRACTED RATE ON NEW HOME MORTGAGES ORIGINATED BY MUTUAL SAVINGS BANKS REGRESSED ON YIELDS ON TEN-YEAR U.S. GOVERNMENT BONDS[a]

Equation	Ten-Year Government Bond Rate: Current	1-Year	R^2	*D-W*	*Rho*
Original Results					
7	.819		.987	2.3	−0.170
	(14.6)				(−.6)
8		.562	.939	2.2	.186
		(3.7)			(.7)
Corrected Results					
7	.887		.981	2.8	−.524
	(15.2)				(−1.6)
8		.020	.876	.9	.020
		(3.4)			(−.03)

[a]The *t*-values are shown in parentheses.

of the data sets revealed a number of data errors, some of which significantly changed the statistical results and conclusions of the studies. Three examples illustrate our findings. We discovered a number of transcription errors in the data set submitted by Giorgio Canarella and Neil Garston (1983) before the manuscript was sent to the printer. While their conclusions are unchanged, correction of the errors caused significant changes in the reported regression estimates and likelihood-ratio test statistics. A sample of the original and published results is shown in Table 3.

Our examination of the data set submitted by Edward Gramlich (1983) revealed a conflict between the sample periods cited in the manuscript and in the data set. While checking this problem, the author discovered that one of the forecasts had been coded incorrectly and was out-of-phase with the other forecast by six months. Correction of this problem substantially changed some conclusions regarding the relative accuracy of the forecasts. The corrected results appear in the published article.

Finally, a minor coding error in the ten-year government-bond-rate series used by Thomas Mayer and Harold Nathan (1983) was discovered after the *JMCB* had gone to press; an "Errata" was subsequently published (1984). While their conclusions were unchanged, the corrected equations are quite different (see Table 4).

IV. Summary of Replications from Submitted Datasets

We conducted replications of nine articles from the *JMCB* as part of the *JMCB Project*. Our choice of articles was limited to those by authors who submitted data sets to the *JMCB*, and we extend our thanks to these authors for exposing their work to our replication efforts. We believe the articles are representative of the *JMCB* in terms of content and econometric sophistication. The number of replications was limited, and we did not in every case attempt to replicate all the results of the article. Our goal was to obtain the same numerical results as had been obtained by the authors and not necessarily to determine whether those results would be confirmed by further scrutiny such as checking the submitted data against original sources. While it is possible that we have erred in these replications, we have made extraordinary efforts to reduce the likelihood of such errors, including contacting the authors to discuss their articles and our replication findings.[2] The replication results are summarized in Tables 5–8.

We replicated the results of two articles in their entirety: James Johannes and Robert

[2]We do not mean to suggest that all authors agree with our findings, only that we have endeavored to keep them informed of our replication efforts.

Rasche (1981) and Robert Engle (1983). Replication was aided greatly by the exceptionally clear, detailed programs and data sets submitted by the authors. Even in these cases we encountered minor problems due to the use of different computer hardware and software. The problems were resolved quickly by contacting the authors. Similar problems appear inherent in replications even when the authors furnish excellent descriptions of their programs and data.

We reproduced exactly almost all the results of V. Vance Roley (1983) and obtained qualitatively similar results for John Merrick (1983). Roley tested the impact of weekly money stock announcements on Treasury bill yields by estimating a three-equation model over each of three sample periods. We were able to replicate from his data set all of Roley's results except his estimates of the third equation (equation (3), p. 350) for the first sample period (see Table 5). Merrick estimated a single-equation model of the determinants of money growth (Table 1, p. 227). Despite our best efforts, we were unable to reproduce exactly his regression estimates. Our regression coefficients do display the same sign and statistical significance as those reported by Merrick except for the coefficient of R^S_{t-2}: our coefficient estimate is negative and insignificant (a value of -0.0001 with a t-statistic of 0.01), while Merrick reports a value of 0.029 with a t-statistic of 4.83 (see Table 6). The reasons for these differences are unknown.[3]

We discovered several computer programming errors in our replications, some minor, some serious. A typical example is Brian Maris (1981). The article cites 1952:III–1977:III as the estimation period (101 observations) while the initial period used for estimation in the computer programs is 1950:III (110 observations); Maris's computed Box-Pierce χ^2 statistics are calculated from 101 residuals, not 110. The FORTRAN program used for estimation erred by attempting to read a number from a memory location beyond the end of an array. This FORTRAN error forces the computer to interpret whatever information is stored in that memory location as a real number, and produces highly unpredictable results. Using

TABLE 5—ESTIMATES OF THE EQUATION NOT REPLICATED FROM ROLEY (1983)[a]

Coefficient	Roley	Our Estimate
β_0	0.0029(.0079)	0.0003(.0085)
β_{10}	−0.0094(.0178)	−0.0025(.0152)
β_{11}	0.0059(.0061)	−0.0030(.0049)
β_{20}	0.0463(.0303)	0.1113(.0475)
β_{21}	−0.0125(.0152)	−0.0476(.0257)
β_{30}	0.0472(.0275)	−0.0312(.0213)
β_{31}	0.0245(.0084)	0.0156(.0057)
β_{40}	0.0275(.0117)	0.0302(.0146)
β_{41}	−0.0073(.0030)	−0.0094(.0041)
β_{50}	−0.0098(.0545)	0.0160(.0374)
β_{51}	−0.0045(.0272)	−0.0067(.0154)
β_{60}	0.0296(.0165)	0.0253(.0192)
β_{61}	−0.0093(.0054)	−0.0085(.0068)
$\bar{R}^2$	0.19	0.19
SEE	0.036	0.035
D-W	1.94	2.05

[a] Standard errors are shown in parentheses; D-W = Durbin-Watson statistic.

TABLE 6—ESTIMATES OF MONEY GROWTH RATE EQUATION FROM MERRICK (1983)[a]

Coefficient	Merrick	Our Estimate
a_0	0.007(1.40)	0.013(2.41)
a_1	0.606(7.97)	0.626(6.85)
a_2	−0.054(−0.58)	−0.039(−0.38)
a_3	0.116(1.27)	0.141(1.40)
a_4	−0.071(−0.78)	−0.047(−0.46)
a_5	0.097(1.24)	0.099(1.14)
a_6	0.075(1.07)	0.065(0.85)
a_7	0.008(2.31)	0.010(2.65)
a_8	−0.005(−1.09)	−0.002(−0.49)
a_9	0.011(1.61)	0.011(1.45)
a_{10}	−0.003(−0.76)	−0.004(−0.93)
a_{11}	−0.273(−3.14)	−0.380(−4.06)
a_{12}	0.306(3.64)	0.361(3.90)
a_{13}	0.029(4.83)	−0.0001(−0.01)
D-W	1.98	1.98

[a] The t-statistic values are shown in parentheses.

[3] One reason may be the differing abilities of numerical algorithms in econometrics computer programs to cope with collinear time-series data. Our results were obtained with version 3.4B of the TSP Econometrics package written in double-precision FORTRAN on an IBM 3081D and also with regression programs written by the authors of this paper in double-precision IBM VS FORTRAN using high-accuracy algorithms from the IMSL computer subroutine library. We believe that authors should investigate the numerical stability of their results and publish the findings.

TABLE 7—BATAVIA AND LASH (1982): PUBLISHED AND REPLICATED RESULTS, *GNP* REGRESSION

		Coefficient		
	Constant	*M*	*H*	*L*
A. *GLS Results*				
Batavia and Lash	−.8116	1.4623	.0722	.2970
	(3.98)	(46.62)	(1.75)	(2.59)
Replication:				
Iterative	.1561	1.2857	.0169	.1736
Method	(.331)	(15.068)	(.471)	(1.399)
Replication:				
Single	−.7533	1.4522	.0708	.312
Iteration	(−3.79)	(47.41)	(1.781)	(2.786)
B. *2SLS*				
Batavia and Lash	.7496	1.4541	.0522	.3358
	(2.34)	(31.31)	(1.30)	(1.61)
Replication:				
Iterative	−.4510	1.3965	.0294	.2775
Method	(−1.408)	(24.66)	(.792)	(1.859)
Replication:				
Single	−.697	1.444	−.0542	.3429
Iteration	(−3.003)	(40.48)	(1.409)	(2.519)

Note: The t values are shown in parentheses. M = Money supply; H = Ratio of high employment government expenditures to high employment tax receipts; L = Ratio of bank loans to bank earning assets.

the time-series filters reported by Maris, we were able to replicate all the results in his article. After correcting the FORTRAN program, we found that the specific time-series filters accepted by Maris were rejected by the data. We then identified and estimated an alternative set of filters which yielded innovations that passed the Box-Pierce test; our corrected results support Maris's causality conclusions.

We could not replicate the results of two articles, in one case even with the active assistance of the author. In Bala Batavia and Nicholas Lash (1982), the authors state that generalized least squares was used for the estimation of both a single-equation and a simultaneous-equation model, but do not present the estimator. The authors were unable to furnish their computer programs and we were unable to replicate the authors' regression estimates from the data set which they furnished. We obtained estimates qualitatively similar to their estimates in magnitude and statistical significance by using a single-iteration Cochrane-Orcutt estimator with the value of ρ fixed at the value reported in the article. The values and significance levels of coefficient estimates obtained from both single-iteration and iterative Cochrane-Orcutt estimators differed greatly from those reported by the authors (see Table 7).

The second replication examined Geoffrey Woglom's 1981 study of the role of stock prices as a determinant of consumption in the MIT-Penn-SSRC (MPS) macroeconometric model. The research reported in the article had been completed several years prior to our request and the data set had been updated since publication of the article; the vintage data set which corresponded to the article itself could not be reconstructed. Woglom furnished his current data set which included revised observations on the variables and time periods used in the 1981 article. Both we and Woglom attempted replication of the article so as to determine whether the loss of the vintage data was important. While ours and Woglom's estimates based on the revised data are very similar, both differ from those contained in his article. Table 8 presents results for his equations 7 and 9 (Table 1, p. 218). Estimates based on the revised data set generally are more consistent than his published estimates with the hypothesis that the non-

TABLE 8—WOGLOM (1981): PUBLISHED, REVISED, AND REPLICATED ESTIMATES OF CONSUMPTION EQUATIONS

	YD	*U·YD*	*VKN*	*FVST*	*RVST*	*F*-Stat for Test of $e > c$
Equation 7 (1963:I–1977:III)						
Original Estimates	.694	−.073	84.5	−38.6	32.2	3.78
	(18.7)	(−.4)	(6.3)	(−2.1)	(1.4)	
Woglom's Replication	.78	−.099	49.75	−11.64	65.65	[a]
	(30.0)	(−1.01)	(5.29)	(−1.12)	(3.83)	
Our Estimates	.716	.177	61.59	−10.51	150.23	4.23
	(12.31)	(.819)	(3.42)	(−1.19)	(2.38)	
Equation 9 (1963:I–1972:IV)						
Original Estimates	.744	−.041	81.9	−75.5	6.6	10.98
	(39.8)	(−.3)	(8.8)	(−3.3)	(.4)	
Woglom's Replication	.777	.198	57.94	−51.65	26.16	[a]
	(27.75)	(.938)	(5.51)	(−1.51)	(1.39)	
Our Estimates	.742	.484	65.02	−50.19	292.34	6.20
	(35.35)	(4.17)	(6.42)	(−5.32)	(6.76)	

Note: The *t*-statistics are shown in parentheses. *YD* is disposable income, *VKN* is the value of nonstock, household net worth, *FVST* is the value of common stocks due to quantifiable factors, and *RVST* is the value of common stocks due to nonquantifiable factors. *U* is a measure of the unemployment rate. The coefficients on *YD*, *U·YD*, *FVST*, and *RVST* are the sums of lag coefficients on second-degree polynomial lags constrained to zero at the tail. The lags on *YD* and *U·YD* are 9 periods (including the present period) and the lags on *FVST* and *RVST* are 7 periods (including the present period).

[a] Not reported.

quantifiable value of stocks reflects expectations of future income. These results emphasize the importance of maintaining intact the vintage data sets used in published articles, especially when continuing research requires that active data sets be updated with revised observations.

Several authors wrote that all or part of their data had been lost but could readily be obtained from published sources. We chose to replicate the results of a typical article in this group (Lawrence Goldberg and Anthony Saunders, 1981). Goldberg and Saunders provided the banking data used in their article but their data on imports, investment, and *GNP* had been lost. They identified the general source for each variable (either the *Survey of Current Business* or *Federal Reserve Bulletin*), but provided no specific months, pages, or table numbers. They stated in materials submitted to the *Project* that they estimated the system of equations in their article by generalized least squares; in subsequent conversation, they explained that the agencies equation was estimated by ordinary least squares and the other two equations by a single-iteration Cochrane-Orcutt estimator. During December 1982 we collected the most-recently published values for all variables and time periods in their model.[4] Our calculated numerical values for the regression coefficients and standard errors differed significantly from those published by Goldberg and Saunders, with some coefficients which had insignificant *t*-statistics in their article becoming significant in the replication and vice versa. We examine this article further in Section V below.

The final replication study which we discuss here concerns a large-scale macroeconometric model. In 1982, the *JMCB* published an article by Benjamin Friedman based on a version of the MIT-Penn-SSRC (MPS) macroeconometric model containing a large model of the market for U.S. government bonds. We requested the programs and data used for the article, appreciating that this could be a complex task. To our knowledge, no one previously had addressed the feasibility of a researcher furnishing the programs

[4] Goldberg and Saunders cited the *Federal Reserve Bulletin* as the source for some data series which also are published in the *Survey*. Since the *Survey* is the primary source for these series, we collected all data from the *Survey*.

and data from a large macroeconometric model to another researcher for replication of an article. In July 1983, the author sent us an 87-page manual describing the installation and usage of the MPS model on Harvard University's IBM VM/370 computer system (Friedman and David Johnson, 1983), and two computer tapes containing more than 2500 files of programs and data.

Our problems in using Friedman's programs and data were the familiar difficulties of moving programs and data across computer systems, complicated by the scale of the MPS model. An accurate appraisal of the time, knowledge, and resources required of another researcher seeking to replicate Friedman's results only could be obtained by installing his MPS model on a computer, in this case, Ohio State University's IBM 4341 VM/CMS system. The Harvard-MPS model system includes a supervisor program written in the EXEC language of IBM's CMS operating system; a set of FORTRAN programs to define the model's equations, load data, and solve the model in simulation; and the NBER TROLL econometrics package to store, retrieve, and analyze simulation output. The model's FORTRAN programs are not integrated into the TROLL system, and communications between them, TROLL, and the user are conducted by the CMS EXEC program handling numerous disk files. We found installation of the TROLL package on the IBM 4341 relatively straightforward, but not a task to be attempted without prior experience with IBM VM computers.

Our most difficult task was converting the CMS EXEC programs from IBM 308X series mainframe computers using IBM 3350-type disk drives to an IBM 4341 CMS computer using 3370-type disk drives. Our limited time, patience, and resources forced us to end this replication effort before we finished the necessary reprogramming. In a subsequent telephone conversation, Friedman estimated that the time and effort required to produce the manual and computer tapes approximated that required to produce an additional article for a professional journal (these materials were compiled specifically in response to our request), and admitted astonishment that anyone would attempt to convert the Harvard-MPS-TROLL system to another computer and use it for replication.

Replication attempts which use large-scale eonometric models are arguably the most complex of all such attempts due to the large computers, programs, and data bases required. A researcher without an IBM VM/CMS computer system would find replication impossible since the programs are fully IBM dependent. As our replication effort demonstrates, even installation on another IBM computer may require a substantial amount of technical expertise (or the research grants to hire it). Nevertheless, the desirability of scientific replication is—if anything—greater with respect to results based on complex computer technology than for smaller more-easily reproducible models.

V. The Importance of Vintage Data in Replication: A Simulation Experiment

A number of authors argued that their data "...could be readily obtained from published sources" and submitted no data or only partial data sets for the *JMCB Project*. Government agencies periodically revise published data such that the value of a variable for a particular time period (for example, gross domestic investment in 1978:II) differs in different issues (volume, number) of the same publication. The difficulty of replication in the absence of original vintage data sets was exemplified above for Woglom; another researcher would replicate an author's data set only by the coincidence of choosing the same issues of a publication as had been chosen by the original researcher.

We conducted a simulation experiment to study the effects of data revisions on the replication of a published empirical article. Our experiment is based on Goldberg and Saunders' three-equation model of the growth of agencies, branches, and subsidiaries of foreign banks in the United States. Our experiment simulates a researcher attempting to replicate Goldberg and Saunders' published results by collecting data from the *Survey of Current Business*. The complete experiment is comprised of 500 trials. Each trial consists of collecting a complete time-series on imports, investment, and GNP from the *Survey* and estimating the Goldberg-Saunders' model. We constructed the data base for the experiment by collecting all preliminary and revised values for imports, investment, and GNP in each of the 40 quarters 1972:IV through 1982:III which had been published in the *Survey of Current Business* through the end of 1982. We used 118 monthly issues of the *Survey*.

Each trial of the experiment begins by drawing an integer in the range [1,118] from a uniform distribution, selecting the corresponding issue of the *Survey of Current Business*, and collecting all observations on imports, investment, and GNP from the issue. This process is repeated until the time-series for the variables are complete. Data once entered on the worksheet are never replaced so that a newer revised number does not displace an older preliminary or revised value already recorded. Each trial has the same number of observations as Goldberg and Saunders' data set. This procedure certainly is not the way Goldberg and Saunders collected their data. Nevertheless, our experiment illustrates the range and frequency distribution of estimates obtainable from randomly selected preliminary and revised data.

In the Goldberg-Saunders model, the values of assets held by agencies, branches, and subsidiaries of foreign banks in the United States are the dependent variables of the first, second, and third equations, respectively. Each equation contains the same independent variables: an intercept term; the lagged spread between yields on assets and liabilities; real gross private domestic investment; the ratio of imports to GNP; and a dummy variable to capture expectations of passage of the International Banking Act. We present below estimates of their model based on the most-recently published (newest) data, the first-ever-published (oldest) data, and the 500 trials discussed above.

In their article, Goldberg and Saunders report only that their model was estimated by generalized least squares; a replicator therefore could reasonably choose either a single-iteration or iterative Prais-Winston estimator. To study how this choice may affect the replication, we repeated our complete experiment for two estimation strategies. In the first, we estimated the agencies equation by ordinary least squares and the other two equations by a single-iteration Cochrane-Orcutt estimator, for comparability to Goldberg and Saunders. In the second, we estimated each equation by ordinary least squares; tested for first-order autocorrelation (Durbin-Watson statistics in the inconclusive region were considered significant); and, if necessary, estimated the equation by an iterative Prais-Winston estimator. We present detailed results only for the coefficient of gross private domestic investment. While this coefficient displayed the worst behavior, the coefficients of the other variables are roughly comparable. The frequency distributions of the coefficient estimates and t-statistics are shown in Figures 1–6 for the Goldberg-Saunders estimator and in Figures 7–12 for the iterative Prais-Winsten estimator.

The most significant finding of the replication experiment is the strikingly different coefficient estimates and significance levels obtained by use of the two different estimators. All 500 trials based on the Goldberg-Saunders estimation procedure produced significant t-statistics at the 5 percent level for the coefficient of investment in all three equations, similar to Goldberg and Saunders' results (see Figures 2, 4, and 6). In trials based on the Prais-Winsten estimator, one-half of t-statistics for the agencies equation (254 of 500), two-thirds of t-statistics for the branches equation (337 to 500), and one-third of t-statistics for the subsidiaries equation (151 of 500) are insignificant (see Figures 8, 10, and 12).

Our experiment demonstrates that Goldberg and Saunders' results are not easily replicated using data from published sources. A researcher using either the most-recently published data or a mixture of vintages of data from the *Survey of Current Business* would be unlikely to reproduce the Goldberg-Saunders findings and, in turn, may be misled regarding the value of Goldberg and Saunders' results as a foundation for future research.

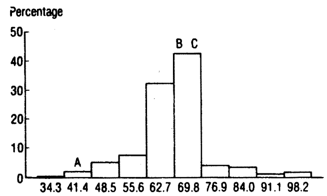

FIGURE 1. AGENCIES EQUATION

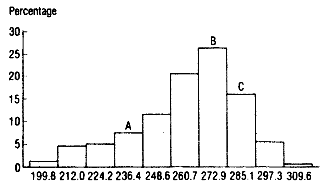

FIGURE 3. BRANCHES EQUATION

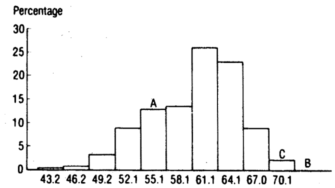

FIGURE 5. SUBSIDIARIES EQUATION

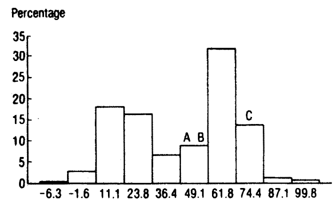

FIGURE 7. AGENCIES EQUATION

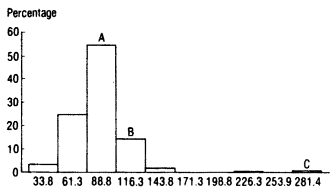

FIGURE 9. BRANCHES EQUATION

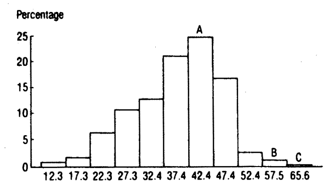

FIGURE 11. SUBSIDIARIES EQUATION

Note: Frequency Distribution of Investment Coefficient (Coefficient value, Midpoint of interval). Figure 1: Ordinary least squares estimator; Figures 3 and 5: Single-iteration Cochrane-Orcutt estimator; Figures 7, 9, and 11: Iterative Prais-Winsten estimator. A = estimate with most recently published data; B = estimate with originally published data; C = estimate in published article.

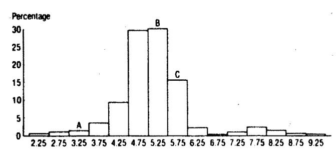

FIGURE 2. AGENCIES EQUATION
INVESTMENT COEFFICIENT

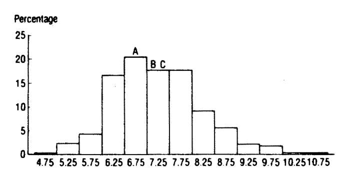

FIGURE 4. BRANCHES EQUATION
INVESTMENT COEFFICIENT

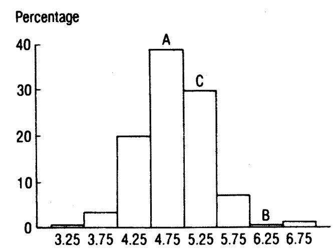

FIGURE 6. AGENCIES EQUATION
INVESTMENT COEFFICIENT

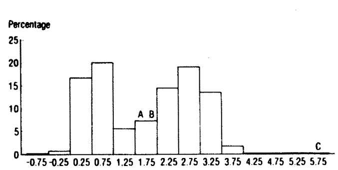

FIGURE 8. AGENCIES EQUATION
INVESTMENT COEFFICIENT

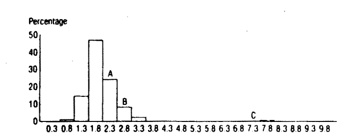

FIGURE 10. BRANCHES EQUATION
INVESTMENT COEFFICIENT

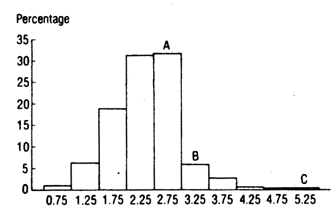

FIGURE 12. SUBSIDIARIES EQUATION
INVESTMENT COEFFICIENT

Note: Frequency Distribution of t-Ratio (Value of t-ratio, midpoint of interval). Figure 2: Ordinary least squares estimator; Figures 4 and 6: Single-iteration Cochrane-Orcutt estimator; Figures 8, 10, and 12: Iterative Prais-Winsten estimator. A, B, C are as defined above.

VI. Replication and Graduate Education in Economics

Several authors have suggested that replication of published empirical studies should be made an important part of graduate education in economics, thereby encouraging new professional economists to regard replication of past research as a legitimate starting point for new research; see, for example, the discussion in Edward Kane. The lack of collected data from published articles has frustrated attempts to implement this suggestion in the past. As a partial remedy, we have publicized the available *JMCB Project* data sets. In August 1983, we wrote to major economics departments with graduate degree programs, advertising the availability of the *JMCB Project* data sets as a basis for replication studies in graduate courses. Since 1983, students in advanced econometrics courses at Ohio State have been required to replicate and extend one published empirical study. Most students have chosen articles by authors who submitted data to the *JMCB Project*.

Overall, we received 59 requests for data between early 1983 and the conclusion of the *JMCB Project* in September 1984. Most requests were from other researchers, but many were from graduate students pursuing dissertation research. The research of Walter Kramer et al. (1985), for example, was greatly simplified by the availability of *JMCB Project* data sets.

VII. Conclusions and Recommendations

The replication of research is an essential component of scientific methodology. Only through replication of the results of others can scientists unify the disparate findings of various researchers in a discipline into a defensible, consistent, coherent body of knowledge.[5] While Ragner Frisch recognized this role of scientific replication in the first issue of *Econometrica*, today no major economics journal except the *JMCB* requests that authors submit programs and data sets. Referees of empirical articles must assume that the programming and data are correct, and readers of the articles find replication a difficult, frustrating, unrewarding, and often impossible task.

It is widely recognized that errors occur in empirical economic research and appear in published empirical articles. Our results from the *JMCB Project* suggest that such errors may be quite common. While many errors appear not to affect the conclusions of the authors significantly, the presence of the errors in a data set frustrates replication and prevents later researchers from building on earlier research. Some authors recognize that their research should build on earlier work but are forced by the unavailability of original data to employ *ad hoc* tests for the comparability of their data with those used in previous studies.[6]

Collinearity of data and high correlations among coefficient estimators are a widely recognized problem in studies based on time-series data. In these circumstances, even slight differences in data values or in the numerical precision of computer programs may produce sharply different parameter estimates. The existence of high collinearity increases both the difficulty of replication and the necessity for the preservation of the authors' original programs and data sets. Authors should appropriately investigate the numerical stability of their estimates and publish the results.

A reviewer of our original NSF funding application argued that the *JMCB Project* was unnecessary because "...all one had to

[5] The existence of a large number of studies which differ in their data sets and statistical estimators but nonetheless accept the same economic models and hypotheses also may provide a consistent body of scientific knowledge. New studies generally present an alternative view or interpretation of observed phenomena and attempt to extend results reached by previous researchers, not to confirm them. Replication is an essential element in the evaluation and unification of the results of any large group of studies.

[6] See, for example, Batavaia and Lash.

do was ask authors for their data." In principle, we agree with the reviewer and with the editorial statement of the *JPE* quoted above: authors of empirical articles should feel a professional responsibility to maintain program and data files for a reasonable amount of time after publication, and to provide these to other researchers. In fact, little benefit accrues to authors by providing programs and data, and little reward accrues to researchers conducting replication studies unless they can show that a major scientist has committed either fraud or a significant error in his research. This situation is not unique to economics, and similar issues regarding the availability of data are present in many fields; see, for example, James Craig and Sandra Reese (1973), Stephen Ceci and Elaine Walker (1983) and references therein.[7]

In this climate, replication may become viewed as a form of professional head-hunting rather than as an essential component of scientific research. Kane likens the process to petroleum exploration and mining. "Success" in replication may come to be defined as the discovery of error or fraud by another researcher, such that a publishable correction or comment arises, and a replicator may seek out those articles (geological sites) which have the highest likelihood of yielding success (oil). Kane's apt analogy illustrates why, in the present system, those authors whose research is the subject of a replication effort may interpret the very *act* of replication as a challenge to their professional competence and integrity. If programs and data were available from journals and replication became commonplace, authors would be less likely to feel threatened by replication, particularly if they have accurately recorded and carefully documented their programs and data.

One of the authors of this article was editor of the *JMCB* during most of the period when the articles included in the *JMCB Project* were published. It would be embarrassing to reveal the findings of the *Project* save for our belief that the findings would be little different if articles and authors were selected from any other major economics journal. In private correspondence, the editor of another major journal (not the *AER*) confided that he shares our belief.

On the basis of our findings, we recommend that journals require the submission of programs and data at the time empirical papers are submitted. The description of sources, data transformations, and econometic estimators should be so exact that another researcher could replicate the study and, it goes without saying, obtain the same results. This policy has three significant advantages.

First, authors would be able to supply programs and data sets at lower cost when their research is just completed than when a published article appears. We found that the frequency and magnitude of errors is smaller in data sets compiled by the researcher immediately after completion of the manuscript than in data sets compiled a year or more later. Furthermore, the compilation of programs and data by authors often uncovered ambiguities, errors, oversights, and misstatements which otherwise would have gone undiscovered.

Second, the journal provides a centralized cost-effective facility for distributing programs and data sets to other researchers. We recognize that journals will incur costs in handling and distributing these materials, costs which will be passed on to subscribers, authors, and those requesting the materials. Our experience at the *JMCB* is that the handling costs of such materials are low. During the last four years, authors have submitted more than 100 data sets on computer cards, magnetic tape, floppy disks, and paper printouts. These materials are stored in a portion of a single filing cabinet and are easily duplicated at low cost. Each requested data set is furnished at the actual cost of duplication including photocopying and computer charges. The organization and quality of submitted data sets is steadily improving, further reducing handling and distribution costs for the *JMCB*. Currently, an undergraduate economics student handles the receipt,

[7] We are indebted to Stephen Stigler for these references.

duplication, and mailing of requested data sets in approximately 2–4 hours per week.[8]

Finally, we believe these costs are more than offset by the benefits. The principal benefit is a reduced frequency of error in empirical articles due to more careful preparation of programs and data than might otherwise be the case. Subscribers benefit from the ability to obtain underlying programs and data. Authors benefit by publishing articles which can be replicated by other researchers, thereby increasing citations to the article and its importance as a basis for further research in the field. Editors and referees benefit by having access to authors' programs and data while evaluating papers for publication. Other researchers benefit by a substantial reduction in the costs of replicating published articles.

Alternatives must be proposed for authors whose research is based upon proprietary, licensed, or confidential programs and data sets such as SAS, SPSS, and Survey Research Center or *National Longitudinal Survey* data bases. Similar problems are rapidly appearing for researchers working on microcomputers, where software licensing agreements expressly prohibit copying or distribution of the software for any purpose. Authors should submit the version and serial numbers of proprietary programs (such as SAS, SPSS, RATS, and TSP) as well as listings of the instructions executed by the program. This audit trail allows replicators to trace bugs in the programs, changes in algorithms, and related difficulties. Users of large proprietary data sets should submit both the serial, version, or identification numbers and the date on which the data set was created or purchased. Although license agreements may restrict authors from furnishing data to other researchers, they should retain a copy of their data since vendors of data often are unable to reproduce the original vintage data set used by the researcher.

We emphasize that, in principle, similar rules should apply to simulation studies. This is a straightforward matter for small studies programmed in FORTRAN or using popular packaged programs. Our experience with the MPS model suggests, however, that formidible difficulties exist for studies based on large-scale models.

[8]No error checking or replication of data sets is currently performed by the *JMCB* or its staff.

REFERENCES

Batavia, Bala and Lash, Nicholas A., "The Impact of Bank Portfolio Composition on GNP," *Journal of Money, Credit and Banking*, November 1982, *14*, 517–24.

Broad, William and Wade, Nicholas, *Betrayers of Truth*, New York: Simon and Schuster, 1983.

Canarella, Giorgio and Garston, Neil, "Monetary and Public Debt Shocks: Tests and Efficient Estimates," *Journal of Money, Credit and Banking*, May 1983, *15*, 199–211.

Ceci, Stephen and Walker, Elaine, "Private Archives and Public Needs," *American Psychologist*, April 1983, *38*, 414–23.

Craig, James and Reese, Sandra, "Retention of Raw Data: A Problem Revisited," *American Psychology*, August 1973, *28*, 723.

Engle, Robert F., "Estimates of the Variance of U.S. Inflation Based Upon the ARCH Model," *Journal of Money, Credit and Banking*, August 1983, *15*, 286–301.

Feige, Edgar, "The Consequences of Journal Editorial Policies and a Suggestion for Revision," *Journal of Political Economy*, December 1975, *83*, 1291–95.

Feldstein, Martin, "Social Security, Induced Retirement, and Aggregate Capital Accumulation," *Journal of Political Economy*, September/October 1974, *82*, 905–26.

Friedman, Benjamin, "Federal Reserve Policy, Interest Rate Volatility, and the U.S. Capital Raising Mechanism," *Journal of Money, Credit and Banking*, November 1982, *14*, 721–45.

______ **and Johnson, David**, "Documentation for Simulation Exercises with the MPS Model as Modified to Incorporate Structural Models of the Corporate and Government Bond Markets," mimeo., Department of Economics, Harvard University, 1983.

Frisch, Ragnar, "Editorial," *Econometrica*, January 1933, *1*, 1–4.

Goldberg, Lawrence G. and Saunders, Anthony, "The Growth of Organizational Forms of Foreign Banks in the U.S.," *Journal of Money, Credit and Banking*, August 1981, *13*, 365–74.

Gramlich, Edward M., "Models of Inflation Expectations Formation: A Comparison of Household and Economist Forecasts," *Journal of Money, Credit and Banking*, May 1983, *15*, 155–73.

Johannes, James M. and Rasche, Robert H., "Can the Reserves Approach to Monetary Control Really Work?," *Journal of Money, Credit and Banking*, August 1981, *13*, 298–313.

Kane, Edward J., "Why Journal Editors Should Encourage the Replication of Applied Econometric Research," *Quarterly Journal of Business and Economics*, Winter 1984, *23*, 3–8.

Kramer, Walter et al., "Diagnostic Checking in Practice," *Review of Economics and Statistics*, February 1985, *67*, 118–23.

Kuhn, Thomas S., *The Structure of Scientific Revolutions*, 2nd ed., Chicago: University of Chicago Press, 1970.

Leimer, Dean R. and Lesnoy, Selig D., "Social Security and Private Savings: New Time-Series Evidence," *Journal of Political Economy*, June 1982, *90*, 606–29.

Maris, Brian A., "Indirect Evidence on the Efficacy of Selective Credit Controls: The Case of Consumer Credit," *Journal of Money, Credit and Banking*, August 1981, *13*, 388–90.

Mayer, Thomas and Nathan, Harold, "Mortgage Rates and Regulation Q," *Journal of Money, Credit and Banking*, February 1983, *15*, 107–15.

______ **and** ______, "Errata," *Journal of Money, Credit and Banking*, May 1984, *16*, 271.

Merrick, John J., "Financial Market Efficiency, the Decomposition of 'Anticipated' versus 'Unanticipated' Money Growth, and Further Tests of the Relation Between Money and Real Output," *Journal of Money, Credit and Banking*, May 1983, *15*, 221–32.

Roley, V. Vance, "The Response of Short-Term Interest Rates to Weekly Money Announcements," *Journal of Money, Credit and Banking*, August 1983, *15*, 344–54.

Siskind, Frederick, "Minimum Wage Legislation in the United States: Comment," *Economic Inquiry*, January 1977, *15*, 135–38.

Welch, Finis, "Minimum Wage Legislation in the United States," *Economic Inquiry*, September 1974, *12*, 285–318.

______, "Minimum Wage Legislation in the United States: Reply," *Economic Inquiry*, January 1977, *15*, 139–42.

Woglom, Geoffrey, "A Reexamination of the Role of Stocks in the Consumption Function and the Transmission Mechanism," *Journal of Money, Credit and Banking*, May 1981, *13*, 215–20.

Editors, "Editorial Comment," *Journal of Political Economy*, December 1975, *83*, 1295–96.