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Monetary Policy and Economic Performance: Evidence From Single Equation Models

By Bryon Higgins and V. Vance Roley

Economists and other analysts generally agree that monetary policy actions taken by the Federal Reserve have an important impact on the economy. This agreement is not, however, accompanied by a consensus on how best to analyze and measure the effects of policy actions. An increasing number of observers argue that policy actions should be measured by movements in the money supply and that the Federal Reserve should focus on the money supply in the implementation of monetary policy. These observers emphasize the money supply because they believe that monetary policy actions affect the economy primarily through their impact on the money supply. Monetarists have presented theoretical and empirical evidence of a close relationship between the money supply and nominal gross national product (GNP) to support this view. Empirical results derived from direct estimation of the relationship between the money supply and GNP using single equation econometric models have been a particularly influential type of evidence provided by monetarists to bolster their position.

Neither monetarists nor others, however, have made extensive use of the single equation approach to investigate the relationship between GNP and financial variables other than the money supply, such as interest rates. Theoretical considerations, however, suggest that interest rates as well as the money supply have important effects on the economy. Thus, economic theory supports the nonmonetarist view that the Federal Reserve should consider the effect of policy actions on interest rates as well as the money supply. In light of these theoretical considerations, the single equation approach is employed in this article to investigate and compare the empirical relationships between GNP and a number of financial variables, including interest rates as well as the money supply. The first section of the article presents a general overview of the way monetary policy actions affect the economy, analyzes the advantages and disadvantages of the single equation approach, and discusses alternative financial variables that may usefully be included when employing the single equation econometric technique. The second section presents empirical evidence derived from use of the single equation approach to compare the relationships between GNP and alternative financial variables.

MONETARY POLICY AND GNP

Researchers have investigated the impact of monetary policy actions on nominal GNP—which measures aggregate spending on goods and services by households, businesses, government, and foreigners—because it is generally believed that policy actions affect the economy primarily by influencing aggregate spending.

Aggregate spending, in turn, directly affects the production of goods and services and the unemployment and inflation rates. Thus, the primary goal of monetary policy is to achieve GNP growth that is consistent with the ultimate objectives of monetary policy—high employment, economic growth, price stability, and a sustainable pattern of international transactions.

General Overview of the Effects of Monetary Policy Actions

Federal Reserve policy actions affect GNP by influencing a wide range of financial and nonfinancial variables that affect spending decisions of households and businesses. The Federal Reserve most directly affects financial variables that are closely related to the reserve positions of banks. The Federal funds rate and the monetary base, for example, are so directly affected by policy actions that they could be controlled with a considerable degree of precision by the Federal Reserve. Financial variables that are less closely related to banks' reserve positions, such as monetary and credit aggregates and market interest rates, are less directly affected by monetary policy actions and are therefore subject to somewhat less precise control by the Federal Reserve. The effects of policy actions on nonfinancial variables are even more remote.

The effects of policy actions are reflected first in financial variables such as the Federal funds rate and the monetary base and are subsequently transmitted to other financial and nonfinancial variables. After affecting the Federal funds rate and the monetary base, policy actions affect banks' willingness to expand loans, investments, and deposits. The adjustment in banks' portfolios results in a change in the yield on a whole spectrum of real and financial assets. These changes in relative yields induce portfolio realignments by other financial and nonfinancial businesses and by households. The resulting changes in the cost of credit and the implicit yields on real assets affect spending behavior of both businesses and households directly. The change in the level of interest rates also affects the market value of the existing stock of bonds, equities, and other assets. The resulting effect on total wealth also influences the spending decisions of consumers. Finally, because of institutional arrangements that constrain lending rates in certain sectors of the economy, a change in the level of interest rates may affect the availability as well as the cost of credit. This credit availability effect also influences spending decisions, particularly in the housing sector.

The response of aggregate spending to monetary policy actions leads to a change in aggregate production and income, which results in further changes in the demand for money and credit. This feedback effect generates additional changes in portfolio choices, the cost and availability of credit and total wealth, which lead to further changes in spending and additional feedback effects.

Because of lagged adjustment of businesses and households and the complexity of the interrelations among various sectors of the economy, the ultimate impact of monetary policy actions on the aggregate demand for goods and services may occur over a period of several months or even years. Thus, it is difficult to predict the timing as well as the magnitude of the effects of alternative policy actions.

Structural Versus Single Equation Approaches to Measuring the Impact of Monetary Policy

There are several possible methods of investigating relationships between GNP and those financial variables that are potentially useful as measures of the effects of monetary policy actions. One method is to employ a disaggregated structural model of the economy to analyze the response of each of the components of aggregate spending to monetary policy actions. This is done by estimating the parameters of several major economic relations thought to be important in the transmission mechanism for monetary policy. The resulting equations are combined to form a structural model of the economy. The model provides a consistent set of empirical relationships that reflects spending responses of economic decisionmakers to policy actions. After the parameters are estimated, the model may be used to predict the effects of policy actions on GNP and on each of the components of aggregate spending.

Another method of analyzing relationships between GNP and financial variables is the single equation approach. In recent years, single equation models of total spending have become increasingly popular as tools for investigating the impact of policy actions. This approach has been used extensively by researchers at the Federal Reserve Bank of St. Louis. As the term implies, a single equation model uses one equation containing one or more key variables to explain movements in GNP without attempting to explain its separate components. A single equation model may be viewed as a summary of, or a "reduced form" solution to, a structural model. Thus, the single equation implicitly incorporates all of the complex interrelationships that are explicitly allowed for in a structural model. In this sense, the single equation and structural approaches to policy analysis and economic prediction are consistent in principle.[1]

A disadvantage of the single equation approach is that it cannot be used to analyze the impact of policy actions on the individual components of aggregate spending.[2] Furthermore, the mechanisms by which policy actions are transmitted to spending behavior of households and businesses cannot be determined within the framework of a single equation model. Thus, it is impossible to discriminate precisely between alternative theories of the exact channels through which monetary policy actions affect the economy using the single equation approach. For some purposes, however, detailed information about the transmission mechanism of policy actions may not be as important as a reliable indication of their total effect on aggregate spending.

One of the primary advantages of the single equation approach is that it does not require detailed knowledge of the structure of the economy. Those who advocate the single equation approach to policy analysis believe that the interrelationships in the economy are too complex to be represented in an econometric model of the economy.[3] If so, it may be preferable to base predictions on the direct relationship between policy actions and total spending rather than risk omission of an important link in the transmission mechanism. Once the relationships between aggregate

1 There can be serious statistical problems in estimating a single equation model when the financial variable used as an explanatory variable was not the variable policymakers tried to control during the period for which the equation is estimated. For a discussion of potential simultaneity bias, see Edward M. Gramlich, "The Usefulness of Monetary and Fiscal Policy as Discretionary Stabilization Tools," *Journal of Money, Credit and Banking*, Vol. 3 (May 1971).

2 If policymakers have a policy horizon long enough to allow for changes in the capital stock, for example, they may sometimes prefer additional investment spending, which increases the capital stock, rather than consumption spending. In this situation, analysis of the effect of policy actions on aggregate demand disguises the possible benefits that would result from changing the current composition of aggregate demand toward greater investment in capital goods.

3 See, for example, Michael W. Keran, "Monetary and Fiscal Influences on Economic Activity—The Historical Evidence," Federal Reserve Bank of St. Louis Review, Vol. 51, No. 11 (November 1969).

spending and financial variables have been estimated empirically by a single equation model, the model may be used to predict the level (or growth) of aggregate demand that would result from particular values of the variables used to measure the influence of monetary policy actions.

The Single Equation Approach and Alternative Financial Variables

Those who use the single equation approach to policy analysis frequently rely on a single financial variable to measure the total influence of monetary policy on aggregate spending. It is very important that the financial variable used in a single equation model be the best single measure of the various influences of monetary policy actions on spending decisions. There is nothing inherent in the single equation approach that dictates the choice of a particular financial variable. Those who advocate the single equation approach to policy analysis, however, have generally favored the use of a monetary aggregate. Thus, the single equation approach has come to be identified with the monetarist view of policy analysis.

Most of the studies that have estimated single equation models of aggregate demand have used the narrowly defined money stock (M1) as the sole financial variable. Some have included a measure of fiscal policy, though, and a few have included a measure of strike activity.[4] The analysts using this approach have generally concluded that the relationship between M1 and aggregate spending is sufficiently reliable to warrant use of a monetary growth target as the method of implementing monetary policy. Since the Federal Reserve cannot control monetary growth directly, however, some analysts have advocated use of the monetary base as the monetary control variable.[5] The monetary base is composed of currency and reserves and is often considered to be a primary determinant of the money supply. Evidence from single equation models indicates that movements in aggregate spending are related almost as closely to the monetary base as to the money stock.

The evidence from single equation models of the close relationship between the growth of aggregate spending and the growth of the money supply has been interpreted by many as strong support of the monetarist belief that the Federal Reserve should focus on monetary and reserve aggregates in the implementation of monetary policy. Indeed, if GNP growth is closely related to monetary growth, it seems plausible for the Federal Reserve to set targets for these aggregates that appear to be consistent with the desired growth in aggregate spending. Thus, the evidence from single equation models has undoubtedly contributed to the Federal Reserve's increased emphasis on monetary aggregates in recent years.

Existing single equation studies, with few exceptions, have not considered the possibility that financial variables other than monetary aggregates may also be closely related to aggregate spending. The relationship between interest rates and aggregate spending, for example, has not been extensively explored within the framework of single equation models. Although there is no theoretical reason for preferring the use of a monetary or reserve aggregate to the use of an interest rate in a single equation model of aggregate demand, those who emphasize the importance of interest

[4] See, for example, Michael Hamburger, "Behavior of the Money Stock: Is There a Puzzle?" *Journal of Monetary Economies*, Vol. 3, 1977.

[5] See, for example, Leonall C. Andersen and Denis S. Karnosky, "Some Considerations in the Use of Monetary Aggregates for the Implementation of Monetary Policy," Federal Reserve Bank of St. Louis *Review*, Vol. 59, No. 9 (September 1977).

rates have generally believed that a more extensive model should be used to analyze their effects on economic activity. One study did, however, compare the explanatory power of a long-term interest rate and the money supply in single equation models of aggregate spending.[6] The empirical evidence led the author to conclude that "changes in interest rates do not give a systematic or consistent indication of monetary influences on economic activity and thus are not a reliable indicator" of the effects of policy actions on total demand.[7] The author concluded that policymakers should rely on movements in the money stock rather than movements in interest rates to measure the effects of policy actions on the economy.

The question of whether there is a close relationship between a short-term interest rate and aggregate spending has been neglected by previous studies employing the single equation approach. There is some reason to believe that movements in money market rates might be a better measure of the short-run effect of policy actions on spending than are movements in long-term rates. While monetary policy actions are reflected quickly in the money market and dominate movements in short-term rates, policy actions are only one of several important factors affecting longer term rates. In particular, the Federal funds rate—the rate on very short-term funds borrowed by commercial banks—is very sensitive to policy actions. Moreover, movements in the Federal funds rate have a major impact on expectations of the future course of monetary policy because the Federal Reserve establishes ranges for the Federal funds rate that seem consistent with attainment of policy objectives. Finally, the extent to which depository institutions ration credit has been determined during several critical periods by the relation of ceiling rates on time and savings deposits to short-term market rates—which are directly affected by the Federal funds rate.

A COMPARISON OF INTEREST RATES AND MONETARY AGGREGATES IN PREDICTING THE IMPACT OF MONETARY POLICY ACTIONS

In this section, the single equation approach is used to empirically investigate and compare the relationships between GNP and four financial variables that may potentially be used to measure the impact of policy actions. The variables are the narrowly defined money stock (M1), the monetary base, the corporate bond yield, and the Federal funds rate. The comparison is based on the relative ability of single equation models of the four relationships to predict changes in GNP. To use the equations to predict changes in GNP, the parameters of the equations were first estimated. The estimation procedures and results are discussed in the next subsection, followed by a discussion of the results of the predictions.

Estimation Results

The four equations are simple relations that have GNP as the dependent variable and the four financial variables as independent variables. In the equations, all variables are annualized quarterly percentage changes, with all variables except the interest rates being seasonally adjusted.[8] Each equation contains a

[6] Michael W. Keran, "Selecting a Monetary Indicator—Evidence from the United States and Other Developed Countries," Federal Reserve Bank of St. Louis Review, Vol. 52, No. 9 (September 1970).

[7] Keran, "Selecting a Monetary Indicator—. . .," p. 12.

[8] Percentage changes of the form $\frac{X_t - X_{t-1}}{X_t}$ were used in computing growth rates for GNP and each of the financial variables. The results for the simple specification of Federal funds rate equation vary somewhat when alternative methods are used to compute growth rates. When positive and negative values of the first differences of logarithms of the Federal funds rate are entered as separate

constant term that is intended to capture the average effects on GNP of variables omitted from the equations.[9] Because the changes in a financial variable may have an impact on spending decisions for a considerable time, each equation contains a distributed lag. The lag allows GNP growth to be explained by movements in the financial variable over a number of past periods.

The equation for the narrowly defined money stock (M1) is:

$$\%\Delta GNP_t = a_0 + \sum_{i=0}^{N} b_i(\%\Delta M1_{t-i}) + e_t,$$

where $\%\Delta GNP_t$ = percentage change in GNP at time t

$\%\Delta M1_{t-i}$ = percentage change in M1 at time t–i

e_t = residual of estimated relationship at time t

a_0, b_i = estimated parameters or coefficients

N = number of past periods a variable is assumed to affect GNP

$\sum_{i=0}^{N} b_i$ = sum of b_i parameters over the current period and N past periods.

The other three equations are similar to the M1 equation.

Each of the equations was estimated for a number of sample periods. The estimation results for the period from the first quarter of 1962 through the fourth quarter of 1977 are representative of the results in all the estimation periods.[10] The results for this period show that the equations for M1 and the base generally conform to those reported in other research.[11] In particular, the positive sums of the coefficients ($\sum_{i=0}^{N} b_i$) in the M1 and base equations indicate that increases in M1 or the base are consistent with increases in GNP. (See Table 1.) Also, the higher corrected multiple correlation coefficient, $\bar{R}^2$, of 0.28 for M1 indicates that M1 is slightly better than the base in terms of ability to explain the changes that occurred in GNP within the 1962-77 sample period. The equation using the corporate bond yield also performs about as expected based on the results of other research.[12] In particular, the equation's $\bar{R}^2$ is

variables in an equation explaining GNP growth, however. the results are similar to those reported for the Federal funds rate equation in this article. For a more detailed discussion of this issue, see Bryon Higgins and V. Vance Roley, "Reduced-Form Equations and Monetary Policy," Working Paper No. 79-1, Federal Reserve Bank of Kansas City, 1979. Growth rates are frequently used in estimating simple relationships between economic time series variables for statistical reasons. See, for example, Michael J. Hamburger, "Indicators of Monetary Policy: The Arguments and the Evidence," **American Economic Review, Vol. 62** (May 1970); Keith M. Carlson, "Does the St. Louis Equation Now Believe in Fiscal Policy?" Federal Reserve Bank of St. Louis **Review, Vol.** 60 (February 1978).

9 The estimated equations do not include any other potential explanatory variables—such as fiscal policy or strike variables—so that the predictive power of the individual financial variables can be isolated.

10 The estimated equations reported are those that resulted from a systematic search procedure over unconstrained and polynomial lags. The properties of the Federal funds rate equation are somewhat more sensitive to the length of the lag than are the properties of the monetary base and M1 equations, perhaps because a large fraction of the explanatory power of the aggregates' equations results from the contemporaneous correlation between the growth of GNP and the growth of the monetary base and M1. For a more detailed discussion of the procedure used to estimate the equations and other issues concerning the estimation results, see Bryon Higgins and V. Vance Roley, "Reduced-Form Equations." The starting date of the period was chosen primarily due to the starting date of the number of past values used to test for the appropriate lag length in the Federal funds rate equation.

11 See, for example, Leonall C. Andersen, "Selection of a Monetary Aggregate for Use in the FOMC Directive," Board of Governors of the Federal Reserve System, **Open Market Policies and Operating Procedures,** 1971.

12 See, for example, Michael W. Keran, "Selecting a Monetary Indicator—Evidence from the United States and Other Developed Countries," Federal Reserve Bank of St. Louis **Review,** Vol. 52 (September 1970).

Table 1
SUMMARY OF ESTIMATION RESULTS FOR THE ALTERNATIVE NOMINAL GNP EQUATIONS
(Sample Period: 1962:Q1-1977:Q4)

Alternative Independent Variables	Estimated Coefficients: Constant (a_0)	Sum of Lag Coefficients ($\sum_{i=0}^{N} b_i$)	$\bar{R}^2$	SE	DW
Narrowly Defined Money Stock (M1)	3.914 (3.3)	0.822 (3.6)	0.28	2.88	1.87
Adjusted Monetary Base	0.724 (0.4)	1.00 (4.0)	0.24	2.96	2.05
Moody's Aa Utility Bond Yield	8.531 (20.0)	−0.097 (−2.6)	0.13	3.18	1.51
Federal Funds Rate	14.53 (11.5)	−0.555 (−5.4)	0.36	2.72	2.37

NOTES: $\bar{R}^2$ equals multiple correlation coefficient corrected for degrees of freedom. SE equals standard error of estimate. DW equals Durbln-Watson statistic.

The M1 equation includes the current and past four quarters of observations estimated with a fourth degree polynomial lag with the left-hand tail constrained to equal zero. The base equation includes the current and past 25 quarters of observations estimated with a third degree polynominal lag. The bond yield equation includes the past four quarters of observations estimated unconstrained. The Federal funds rate equation includes the past 24 quarters of observations estimated with a sixth degree polynomial lag wlth both tails constrained to equal zero.

Numbers in parentheses below coefficient estimates are t-statistics.

relatively low. The sum of the b_i coefficients has a negative sign as expected, indicating that increases in the bond yield are accompanied by decreases in the growth of aggregate spending.

The equation using the Federal funds rate is especially interesting because a short-term interest rate previously has not been considered in single equation models of aggregate spending. As shown by the sum of the b_i coefficients, the estimation results indicate that increases in the Federal funds rate result in decreases in GNP growth. (See Table 1.) Additional results not shown in Table 1 indicate that increases in the Federal funds rate over the preceding 24 quarters have a uniformly negative impact on GNP.[13] Finally, the $\bar{R}^2$ is higher for the Federal funds rate equation than for equations using M1, the base, and the corporate bond yield, indicating that the Federal funds rate has a slightly greater ability

13 The finding that the total interest rate effects occur with long lags is not unique to this study. See, for example, Dale W. Jorgenson, "Capital Theory and Investment Behavior," American Economic Review, Vol. 53 (May 1963). Andersen and Karnosky also find that lags of 24 quarters may be appropriate when considering the total impact of changes of M1. See Leonall C. Andersen and Denis S. Karnosky, "The Appropriate Time Frame for Controlling Monetary Aggregates: The St. Louis Evidence," Federal Reserve Bank of Boston, *Controlling Monetary Aggregates II: The Implementation*, 1973.

to explain changes in GNP within the sample period.[14]

A Comparison of Predictive Performance

This section compares the four single equation models of GNP in terms of their ability to predict GNP growth a year in advance. The predictive performance for yearly periods is particularly relevant because the Federal Reserve currently uses a one-year planning horizon in establishing growth ranges for the monetary aggregates. The procedure used in the comparison of the predictions of GNP growth may be illustrated by reference to the predictions for 1970. To predict the growth of GNP in 1970, the equations were estimated using data only through 1969. These estimated equations, along with actual values of the financial variables in 1970, were then used to predict GNP growth in 1970.[15] Finally, the predicted values for GNP were compared with actual GNP for 1970. This procedure was followed for each year during the period from 1965 through 1977.

For each yearly prediction period, two statistical measures were used to compare the predictive performance of the four equations. One measure is the prediction error, which is the arithmetic average of the quarterly differences between actual and predicted GNP growth. The second measure is the root-mean-square error, which reflects the variability of the individual quarterly prediction errors within each year.[16] In 1977, for example, the M1 equation had the smallest prediction error with a value of —1.42—that is, the quarterly GNP growth rates, predicted using the M1 equation, averaged 1.42 percentage points lower than actual average GNP growth. (See Table 2.) The corporate bond rate equation had the lowest quarterly root-mean-square error with a value of 2.81, indicating that the variability of the four individual quarterly prediction errors within 1977 were the smallest for this equation. In other years, however, the base or the Federal funds rate equations had the lower prediction or root-mean-square errors. Thus, no firm

14 As is common with highly aggregative single equation models of aggregate spending, all of the estimated equations have some theoretical and statistical problems. For example, the current values of both M1 and the base are included in their respective equations (Table 1), which may result in simultaneity bias. That is, the direction of causation between neither M1 and GNP nor the monetary base and GNP is readily apparent. This problem is particularly troublesome in these equations because of the large values of the current quarter coefficients (b_0 = 0.59 for M1, b_0 = 0.58 for the base). The corporate bond rate equation is plagued by extremely poor explanatory power and an implausible lag structure. The Federal funds rate equation has an implausibly large constant term, implying untenable long-run properties of the relationship between changes in the funds rate and GNP growth.

15 This procedure using historical values of the alternative financial variables may bias the results because it assumes implicitly that the values of each financial variable could have been controlled with equal precision. The possible bias is especially prevalent for M1 and the long-term bond yield because of the Federal Reserve's inability to exercise precise control over their values.

16 Let $\%\Delta GNP_i^p$ and $\%\Delta GNP_i^a$ be the predicted and actual values, respectively, of GNP growth during the i-th quarter of a given year. The prediction error (PE) for the year is computed as

$$PE = \sum_{i=1}^{4} [(\%\Delta GNP_i^p) - (\%\Delta GNP_i^a)]/4,$$

where the individual quarterly values are divided by 4 because all data were annualized for estimation and prediction purposes. In 1977, for example, the individual quarterly prediction errors— $(\%\Delta GNP_i^p) - (\%\Delta GNP_i^a)$ — using the M1 equation were —2.82, —5.11, 1.16, and 1.09, implying an annual prediction error of —1.42.

The quarterly root-mean-square error is computed as

$$\text{RMSE (quarterly)} = \sum_{i=1}^{4} [(\%\Delta GNP_i^p) - (\%\Delta GNP_i^a)]^2/4)^{1/2}$$

Again using the individual quarterly prediction errors in 1977 for the M1 equation, the root-mean-square error equals 3.02.

Table 2
ERRORS IN PREDICTING GROWTH RATES OF NOMINAL GNP USING AGGREGATES AND INTEREST RATES

	Measures for Annual Prediction Periods							
	Prediction Error				Root-Mean-Square Error			
Prediction Period	M1	Base	Corporate Bond Rate	Federal Funds Rate	M1	Base	Corporate Bond Rate	Federal Funds Rate
1968	1.04	-1.94	-2.54	-1.14	1.82	2.82	4.04	1.99
1969	1.79	-0.97	1.66	-1.92	2.20	2.11	2.83	2.49
1970	2.20	1.54	2.62	1.44	3.32	2.82	3.02	3.27
1971	-0.77	-1.75	-2.48	1.39	3.60	4.03	4.86	4.81
1972	-2.50	-2.91	-3.57	-0.87	2.77	3.57	3.82	2.62
1973	-1.85	-0.54	-2.90	-1.97	3.41	2.65	3.85	3.41
1974	0.86	3.08	-0.05	1.50	2.59	3.52	2.06	2.16
1975	-3.28	0.01	-2.97	-0.09	5.93	5.34	7.07	4.92
1976	-0.63	0.30	-0.43	0.51	2.18	2.10	2.57	1.86
1977	-1.42	-2.32	-2.33	-1.45	3.02	3.81	2.81	3.46
	Summary Measures							
	Average Absolute Prediction Error				Root-Mean-Square Error (Annual Predictions)			
	1.63	1.54	2.16	1.23	1.82	1.84	2.40	1.35

conclusion can be made about the predictive performance of the four equations on the basis of the individual yearly prediction periods. Firm conclusions require examining the results for the **1965-77** period as a whole.

For the **1965-77** period as a whole, two summary statistical measures were used to compare the predictive performance of the equations. One is the average absolute prediction error, which is the average of the absolute values of the prediction errors for all of the years. The other measure is the root-mean-square error of the yearly predictions, which reflects the variability of the prediction errors for the **1965-77** period as a whole.[17] These summary measures uniformly favor the equation using the Federal funds rate as the best predictor of **GNP**. In particular, the average absolute prediction error is lower for the Federal funds rate equation than for the other equations. This measure indicates that the predicted values of annual GNP growth differed from actual GNP growth by an average of **1.23** percentage points during the **1965-77** period. (See Table 2.) The annual root-mean-square error of **1.35** indicates that the

[17] Let PE_j represent the prediction error for the j-th year. The average absolute prediction error (AAPE) is then computed as

$$\text{AAPE} = \sum_{j=1}^{10} PE_j/10.$$

The root-mean-square error for the annual predictions is computed as

$$\text{RMSE (annual predictions)} = \left[\sum_{j=1}^{10} (PE_j)^2/10\right]^{1/2}.$$

variability of the annual predictions was also the lowest for the Federal funds rate equation. The aggregates equations do the next best, but the evidence is mixed concerning whether M1 or the base performs better. The equation using the corporate bond yield is the least desirable as judged by either summary measure of predictive performance.

CONCLUSION

There are a number of methods for determining the impact of monetary policy actions on the economy. One method that has become increasingly popular in recent years is to include a single financial variable that is thought to summarize the total effect of policy actions in a single equation model of aggregate spending. Those who employ the single equation approach have generally restricted their attention to the relative ability of monetary aggregates to explain changes in aggregate spending. Because of theoretical considerations indicating that interest rates may have an important impact on aggregate spending, the single equation approach was adopted in this study to explore the potential usefulness of interest rates as well as monetary and reserve aggregates in the implementation of monetary policy.

The empirical results of this study indicate that predictions of aggregate spending based solely on past movements in the Federal funds rate are more accurate than predictions based solely on current and lagged movements in M1, the monetary base, or a long-term interest rate. Although different specifications of the single equation models might alter the results, the empirical evidence in this study indicates that the Federal funds rate is the best single financial variable for the Federal Reserve to use as a measure of the effects of monetary policy actions.

The empirical results also indicate, however, that all of the financial variables tested leave a large percentage of the variation in total spending unexplained. Thus, the evidence does not support the proposition that aggregate spending depends exclusively on a single financial variable. Fortunately, the Federal Reserve need not rely exclusively on a single financial variable in determining the appropriate course for monetary policy. Information on a large number of economic variables is available to the Federal Reserve, and judicious use of the information from all of these variables may be preferable to exclusive focus on any single financial variable.

Preliminary Estimates of GNP: 1972-78

By Dan M. Bechter and Steven P. Zell

Economic policymakers need reliable, comprehensive, and timely data on U.S. business and financial conditions. The most comprehensive measure of the country's economic activity is its gross national product (GNP). Data on GNP and its components are part of the national income and product (NIP) accounts, maintained by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. Since these accounts are estimated for calendar quarters as well as for years, the "Estimates . . . have become an indispensable tool for formulating and evaluating economic policy. . . ."[1]

The BEA publishes its first estimate of a quarter's NIP data about 15 days after the end of that quarter. For example, the first, or preliminary, estimate of GNP for the fourth quarter of 1978 will be published on or about January 15, 1979. The NIP accounts for a particular quarter are then revised several more times, including a revision each July for the following three years.

This article has two purposes. The first is to provide a summary of how BEA arrives at its preliminary estimates of GNP. The second is to assess the reliability of these estimates over the, most recent business cycle.

1 Allan H. Young, "Reliability of the Quarterly National Income and Product Accounts of the United States, 1947-1971," Bureau of Economic Analysis Staff Paper No. 23, July 1974.

DEFINITION AND ESTIMATION

The major components on the product (GNP) side, as opposed to the income side, of the NIP accounts are personal consumption expenditures, gross private domestic investment, government expenditures, and net foreign investment. These four categories define the respective purchases of the four major sources of aggregate demand in the economy: consumers, businesses, governments, and foreigners. Every final good or service produced in the country during a particular period must, by definition, be purchased by one of these sources of aggregate demand.[2] Thus, the basic approach to measuring the economy's total production, or GNP, during a particular quarter is conceptually straightforward: find out how much each of the four major sources of demand spent on final goods and services produced over the quarter.

2 Only final purchases need be counted, since the value of production at intermediate levels is already included in the final price. Changes in business inventories are included in gross private domestic investment to adjust final sales for the difference between unsold goods produced in the current period and goods sold in the current period that were produced in an earlier period.

Unfortunately, the conceptual simplicity of the approach to determining quarterly GNP is not matched by simplicity in its implementation.

Quarterly GNP cannot be constructed from a monthly GNP series, for such a series does not exist. However, the many thousands of monthly economic series that are available, together with special surveys by the BEA, provide a basis for preliminary estimates of quarterly GNP. Still, as will be apparent in the following discussion, the coverage and reliability of the data available to the BEA are far from ideal, giving rise to errors in preliminary estimates of quarterly GNP. A summary of the estimation procedure for each of the major sources of aggregate demand indicates some sources of these errors.

Personal Consumption Expenditures

As defined in the NIP accounts, personal consumption expenditures (PCE) include most of what is commonly considered household purchases of goods and services. The major exception is in the treatment of housing. By convention, the purchase of a new home and expenditures to add to or improve existing homes are not considered part of PCE, but as part of gross private domestic investment. In effect, the household is considered a business in matters of residential investment. In addition, since rents paid to landlords are treated as a measure of services (shelter) from rented housing, personal consumption expenditures on services also include an amount of imputed rent for owner-occupied housing.

Consumers purchase over three-fifths of GNP. More than half of these purchases are consumer goods.[3] The fact that consumer expenditures are so large in GNP is one of the reasons for the existence of a monthly retail sales series that tracks the goods portion of PCE quite well.

To arrive at its preliminary quarterly estimate of goods purchased by consumers, BEA makes several adjustments to the retail sales figures for the months in that quarter. There are three major reasons for these adjustments. First, not all sales by retail stores are to consumers. Prime examples are sales of new cars to businesses, which are counted as part of business purchases, and sales by lumberyards and other building materials stores, most of which are reflected in figures for investment in structures. Second, not all sales by retail stores are sales of new goods. Sales of used cars by automobile dealers are a good example. Except for an amount indicating markup over cost, which reflects the preparation and sales services of the dealer, the value of used cars purchased during a quarter does not belong in a measure of productive activity (GNP) in that quarter. Third, not all sales by retail stores are sales of goods. Sales by gasoline service stations, for example, usually include significant revenue from maintenance, assistance, and repair services. While most of these sales of services reflect consumer expenditures, they are properly counted as PCE-services rather than PCE-goods.

The available data are not as good for making preliminary quarterly estimates of PCE-services as they are for PCE-goods. In arriving at its estimates of consumer spending on services, BEA draws on many public and private data sources; conducts surveys of service establishments; and makes "... considerable use of proxy variables and trend extrapolations. . . ."[4] For example, estimates

3 In the 14 quarters of economic expansion since the trough of the recession in March 1975, PCE has averaged 64 per cent of GNP, and consumer purchases of goods have averaged 55 per cent of PCE, or 35 per cent of GNP.

4 *Report of the Advisory Committee on GNP Data Improvement,* 1977, p. 165.

of consumer spending on many types of services, such as haircuts, travel accommodations, and movies, are made from a monthly survey of selected services establishments conducted by the U.S. Bureau of Census. Estimates of consumer expenditures on electricity, natural gas, and telephones are made from monthly sales data collected by individual companies and their industrial associations. Estimates of consumer spending on legal, medical (except hospital), religious, and private educational services are made by fitting trends to annual levels.

Preliminary estimates of PCE can be no better than the data, assumptions, and procedures on which these estimates depend. The estimation procedures used by BEA undergo constant study and improvement. However, even the best of statistical techniques does not eliminate errors due to lack of reliable data or possible incorrect assumptions made to compensate for data inadequacy. The use of monthly data for making quarterly estimates seems reasonable, but when preliminary quarterly estimates must be made, complete data for the last one or two months in the quarter may not yet be available. As a result, projections of data for these months are required.

Less serious, yet definite sources of error in preliminary estimates of quarterly GNP, are instances when the monthly data are themselves in tentative, preliminary form. A month's retail sales data, for example, are revised regularly in each of two successive months to reflect a larger sample coverage, and are revised irregularly from time to time to reflect improvements in the sampling and estimation techniques. In the cases where trend extrapolations are used as estimates of consumer expenditures on certain services, the assumption that the average increase of the past is being experienced in the current quarter is no more than a best guess. Trend estimates are therefore subject to substantial revision when a quarter's actual experience is unexpectedly abnormal, as shown by data that become available after the preliminary quarterly estimates are made.

Gross Private Domestic Investment

Preliminary quarterly estimates of gross private domestic investment (GPDI) are, like the estimates of PCE, built from estimates of its components. In the case of GPDI, the major components are investments in (1) residential buildings, (2) nonresidential buildings, (3) business equipment, and (4) business inventories.

For its preliminary quarterly estimate of investment in structures, both residential and nonresidential, BEA uses a monthly series of the value of new construction put in place (Census). Only two months of data from the latest quarter are available at the time of the preliminary estimate; the third month must be projected.

Sometimes, available monthly data are not completely "hard" themselves, but include projections. A quarterly estimate can then involve two or more levels of projection, as is the case for the preliminary quarterly estimate of residential structures. As noted, the first estimate requires projecting one month of residential construction activity.[5] However, even the two months of data that are available on the value of new residential construction put in place are based partly on projections. Specifically, the investment expenditures on single-family homebuilding during a month is a

[5] A projection is not necessarily a blind trend extrapolation. It usually reflects the consideration of other data sources and information likely to be relevant to the estimate being made. For example, the effects of unseasonably bad weather on construction, sales, etc., can be estimated from past experience, and these effects can be reflected in the projection.

projected amount based on an assumed rate at which the construction of a home is completed once it is started. Thus, the preliminary quarterly estimate of investment in residential structures actually depends largely on the monthly series of housing starts and on estimates of the average value of units started each month. Finally, the monthly Census estimate of expenditures for additions and alterations of existing residential structures, included in the value of new construction put in place, is an estimate based on historical trend, and this projection becomes incorporated in the preliminary estimate of quarterly GPDI.

Expenditures for petroleum and natural gas drilling and exploration are also part of investment in structures in the NIP accounts. These expenditures are the only part of the quarterly estimates not derived from the monthly Census series of the value of new construction put in place. For a preliminary quarterly estimate of oil and gas drilling, BEA uses industry sources for monthly footage drilled, multiplied by an estimated cost per foot drilled, derived from an industrial price index.

Preliminary quarterly estimates of business expenditures on equipment, the "producers' durable equipment" category in the NIP accounts, are made for four major subcategories. Business purchases of automobiles are assumed to be the same fraction of total new car sales, calculated from monthly trade-source data, as in the preceding year. Business purchases of trucks are estimated from a trade source on unit sales by franchised dealers, together with the producer price index for trucks. Census data on commercial sales of aircraft are the basis for preliminary estimates of business purchases of airplanes. For estimates of investment expenditures on most other types of producers' durable equipment, the BEA relies on monthly Census data of manufacturers' shipments of selected capital goods. The BEA also assumes that the prior year's composition of imports and exports can be used to estimate the capital goods components of imports and exports, as tracked by the monthly Census series on merchandise trade. In making preliminary quarterly estimates for all four of these subcategories of producers' durable equipment, and therefore for the total itself, only two months of data for that quarter are available.

The remaining major category of GPDI is investment in inventories, or changes in business inventories. Changes in farm business inventories are estimated from projections by the U.S. Department of Agriculture. Changes in nonfarm business inventories at the manufacturing, wholesale, and retail levels are all estimated from monthly series compiled by Census, Again, inventory data for only two months of the quarter are available when preliminary quarterly estimates are made.

Government Purchases of Goods and Services

Preliminary quarterly estimates of Federal purchases of goods and services are based, in general, upon monthly data available for two months of the quarter. Data are more fragmentary for preliminary quarterly estimates of purchases of goods and services by state and local governments.

For the first two months of a quarter, Federal purchases are estimated primarily from the U.S. Treasury Department's "Monthly Statement of Receipts and Outlays of the United States Government." The items in this statement are not strictly equivalent to NIP account definitions, so BEA must translate cash outlays into Federal purchases of goods and services. For its preliminary quarterly estimate, BEA must project the third, or missing, month's purchases after obtaining estimates of third-month expenditures from the agencies responsible for most of Federal Government purchases. These agencies include the Department of Defense, the Department of Energy, the Commodity Credit Corporation, and the National Aeronautics and Space Administration. Two other major categories of Federal purchases are employee compensation, estimated from Civil Service Commission's monthly payroll data, and Federal expenditures for construction, estimated from the monthly Census series of new construction put in place.

In developing quarterly estimates of GNP components, some of the most serious deficiencies in data are in state and local government purchases, which is particularly unfortunate because of the extremely rapid growth of purchases by state and local governments. The quarterly estimates, and especially the preliminary quarterly estimates, of purchases by state and local governments are ". . .based heavily on trends and extrapolations of annual data, and judgment."[6] For most of the subcategories of state and local government purchases, only one month of data is available at the time of the preliminary estimate. So, as a result, chances of error in this sector are especially acute and are camouflaged only by usually consistent patterns, which tend to make projections more reliable.

Net Exports of Goods and Services

The rest-of-the-world component of **GNP** is sometimes called "net foreign investment," but net exports of goods and services, or the difference between exports of goods and services and imports of goods and services, describes it better.' Exports and imports of goods are easier to estimate than are exports and imports of services. Preliminary quarterly estimates of foreign trade in goods are constructed from monthly Census data on imports and exports of merchandise. Preliminary estimates of a quarter's exports and imports of services are mainly projections, based on trend extrapolations from a variety of sources of primarily annual data, and modified when trend estimates are believed to misrepresent actual developments. Partly because of the increasing importance of the rest of the world to the U.S. economy, NIP account users and analysts have been studying ways to improve the reliability of quarterly estimates of net exports of goods and services.

RELIABILITY OF PRELIMINARY ESTIMATES

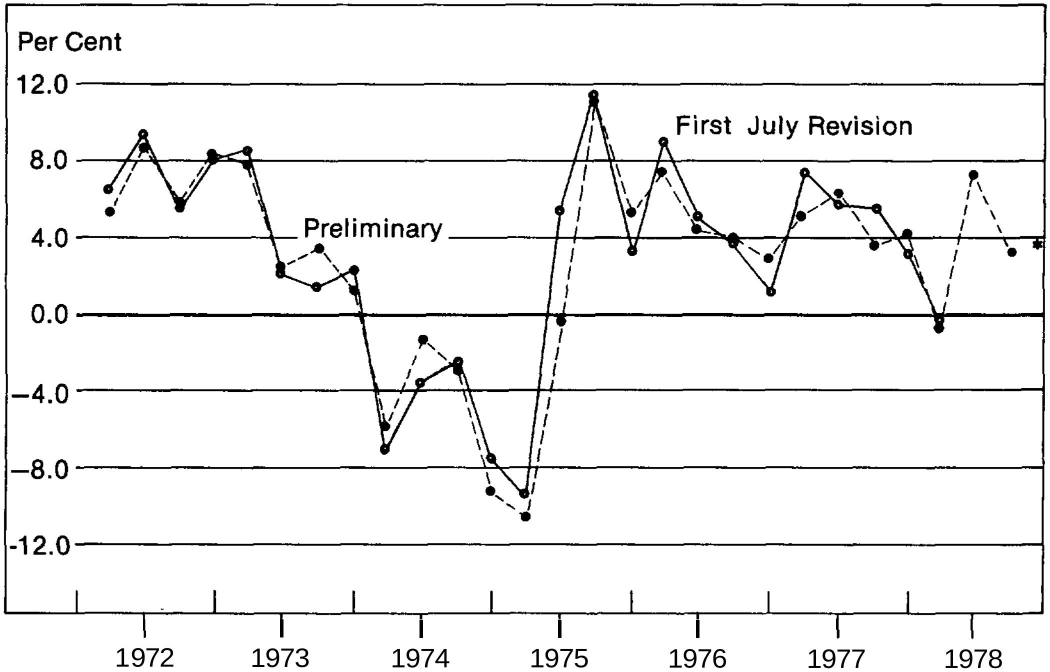
Despite the data inadequacies associated with making preliminary quarterly estimates of GNP, these estimates have been found to be useful indicators of economic activity.[8] The

6 *Report.* p. 196.

7 Goods and services produced in this country but sold to foreign buyers are exports of goods and services. These exports are clearly all part of the nation's national product. Why, then, is it necessary to subtract imports of goods and services from exports to arrive at GNP? The answer is that, in summing up the purchases of consumers, businesses, and governments, no distinction is made between goods produced domestically and those imported from other countries. In effect, imports have been counted in aggregate demand, so they must be subtracted out if a measure of output (GNP) is the objective. Making the subtraction in the rest-of-the-world account accomplishes this purpose and also provides a meaningful summary statistic of the nation's balance of trade.

8 Several studies have been made of the changes in the estimates of quarterly GNP as the original estimate proceeds from its preliminary stage, through several revisions, on to its ultimate final value. Among these are George Jaszi, "The Quarterly National Income and Product Accounts of the United States, 1942-62," paper presented at the 1963 meetings of the International Association for Research in Income and Wealth, published in ***Studies in Short-Term National Accounts and Long-Term Economic Growth;*** Simon Goldberg and Phyllis Deane, ed., ***Income and Wealth: Series XI,*** 1965; Rosanne Cole, ***Errors in Provisional Estimate of Gross National Product,*** National Bureau of Economic Research Studies in Business Cycles No. 21, 1969; and Allan Young, *op.cit.*

Chart 1
GROWTH OF REAL GNP: QUARTERLY, 1972:1 TO 1978:1
PRELIMINARY ESTIMATES AND FIRST JULY REVISED ESTIMATES
(Per Cent Changes At Annual Rates)



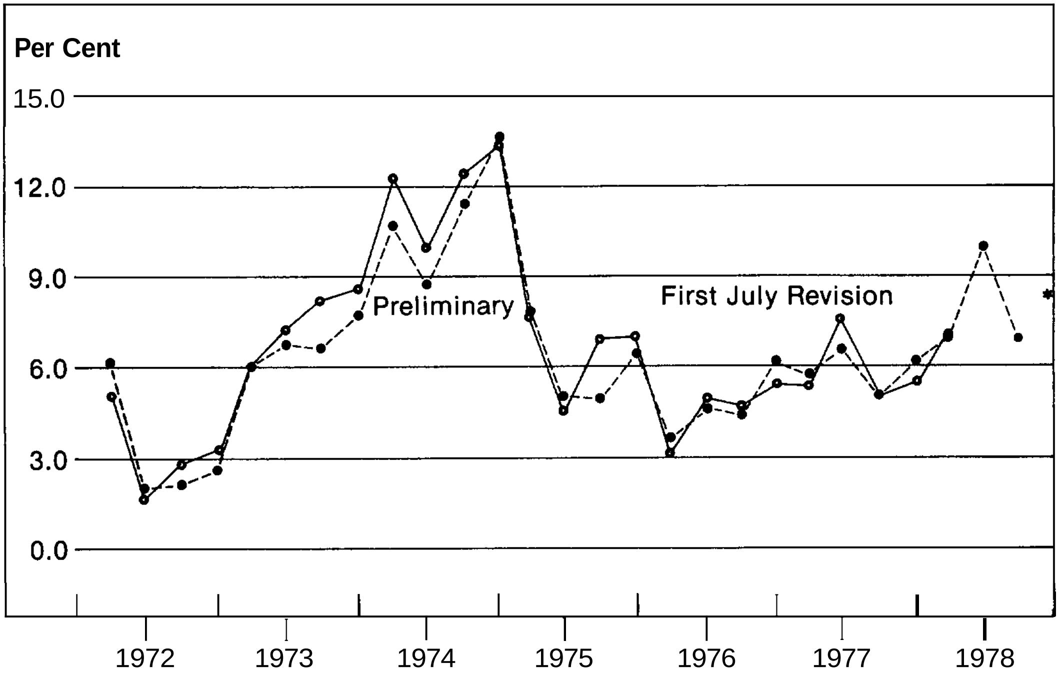
'Fourth quarter 1978 projection.

most recent study of preliminary GNP estimates covered a period ending with the fourth quarter of 1971. Since that time, however, the economy has been through a complete business cycle, including the most severe postwar recession on record, and the national income accounts have undergone another major "benchmark" revision. Another look at the reliability of preliminary estimates of quarterly GNP is warranted.

Economic analysts generally have a fairly good idea of the level of economic activity, so their attention is commonly focused on changes in GNP. Back when inflation was not a problem, the rate of growth of GNP itself was the summary statistic depended on to indicate how fast and in what direction productive activity was changing. But now with inflation high and variable, the rate of growth of GNP unadjusted for price changes is not very meaningful. However, the rate of growth of GNP is the sum of the rate of growth of real GNP (GNP adjusted for changes in prices) and the rate of inflation. Preliminary quarterly estimates of both the economy's rate of growth and rate of inflation are therefore now the indicators of most interest to economic policymakers.

How reliable have been these preliminary estimates in recent years? To answer this question, some other later estimates must be chosen as a basis of comparison. In Chart 1, preliminary estimates of growth in real GNP are compared with "first July" revised

Chart 2
THE RATE OF INFLATION AS MEASURED BY THE IMPLICIT PRICE DEFLATOR: QUARTERLY 1972:1 TO 1978:1 PRELIMINARY ESTIMATES AND FIRST JULY REVISED ESTIMATES
(Per Cent Changes At Annual Rates)



'Fourth quarter 1978 projection.

estimates. The same kind of comparison is made in Chart **2,** for estimates of the rate of inflation as it is measured by the implicit price deflator of **GNP.**[9] The charts show that preliminary estimates have tracked the rate of growth of real **GNP** and inflation quite well, using first July revisions as proxies for "actual" growth and inflation in the economy. In particular, Chart **1** shows that the preliminary estimates captured the downturn in the business cycle when the economy went from expansion in the fourth quarter of **1973,** as indicated by a positive per cent change in real **GNP,** to recession in the first quarter of **1974,** as indicated by a negative rate of growth, or decline, in real **GNP.** Again, when the economy bottomed out in the first quarter of **1975,** the preliminary estimate narrowly missed the trough of the recession by estimating second quarter **1975** real growth to be slightly negative instead of strongly positive.

Charts **1** and **2** give visual impressions of the

[9] First July revisions in GNP are those made each July for the four quarters ending with the first quarter of the year of that July. For example, in July of 1978, quarterly GNP estimates for the quarters 1977:2 through 1978:1 receive their first July revisions. The word "first" is used because estimates are revised for the three prior years (12 quarters) each July, so each quarterly estimate ends up getting a first, second, and third July revision.

reliability of preliminary estimates of the rate of growth of GNP and inflation. Using the same data, numerical measures of reliability can be calculated. Two such numerical measures, bias and dispersion, are useful and easily calculated summary statistics.

Bias is the average difference between the earlier and later estimates. For example, if a preliminary estimate differs from a first July revised estimate by $+2$ percentage points in one quarter and -2 percentage points in the next quarter, the average difference or bias is 0 for those two quarters. When preliminary estimates exhibit negative bias over a period, it means that the preliminary estimates are systematically underestimating actual changes, as defined here by first July estimates.

Dispersion is the average **absolute** difference between the earlier and later estimates. Thus, in the two-quarter example of the preceding paragraph, dispersion $= (|+2|+|-2|)/2 = 4/2 = 2$. A measure of dispersion gives an idea of the accuracy of the earlier estimates as compared with the later estimates over the period.

Table 1 reports values of bias and dispersion for preliminary estimates of the rate of growth of real GNP and of the implicit GNP deflator as compared with first July estimates of the same variables. Besides showing the statistics for the period as a whole, values of bias and dispersion are shown also for the most recent two-year subperiod. This subperiod begins with the first quarter of 1976, just after the extensive "benchmark" revision of the NIP accounts in January 1976.

The tabulated results indicate that, for the period as a whole, preliminary quarterly estimates tended to underestimate the rates of real growth and inflation by the same amount (bias $= -.03$ percentage points). Revisions of preliminary estimates of real GNP growth tended to be larger (dispersion $= 1.3$) than revisions of preliminary estimates of the rate of inflation (dispersion $= 0.7$). In the recent two-year subperiod, there is little indication of improvement in the preliminary estimates of the rate of growth of real GNP, but a hint of some improvement in preliminary estimates of the rate of inflation.

Table 1
MEASURES OF REVISIONS IN QUARTERLY PERCENTAGE CHANGES IN REAL GROSS NATIONAL PRODUCT AND IMPLICIT PRICE DEFLATOR (Preliminary Vs. First July Estimates, 1972:1 to 1978:1)

Period and Item	Bias (% Points)	Dispersion (% Points)
1972:1 to 1978:1	–0.3	1.3
Real Gross National Product	–0.3	1.3
Implicit Price Deflator of GNP	–0.3	0.7
1976:1 to 1978:1		
Real Gross National Product	–0.4	1.2
Implicit Price Deflator of GNP	0.1	*0.5*

NOTE: The quarterly percentage changes used in these calculations of bias and dispersion are at annual rates.

The performance of preliminary estimates in this recent 6-year period can also be compared with the performances of these estimates in earlier periods, as reported by other researchers. To be fair in making such comparisons, however, slightly different measures of reliability must be employed in the cases of those variables subject to distortion by inflation. These modified measures of bias and dispersion are required because unmodified measures have been larger in the **1970's** than in the 1950's and **1960's**, due to the higher rates of inflation in the 1970's. That is, a one percentage point bias or dispersion in a preliminary estimate of, for example, the rate of inflation during a noninflationary period indicates a larger **relative** revision than the same percentage point "error" during a period of rapidly rising prices.

Measures of relative bias and relative dispersion provide a fair basis for comparing the reliability of preliminary estimates in different periods. As their names imply, relative bias and relative dispersion are ratios. Relative bias is defined as bias (the average difference between the earlier and later estimates) divided by the average of the later estimate. For example, if the preliminary estimate of the rate of growth of current dollar GNP misses the first July estimate by +1 percentage point on the average (its bias), and if the rate of growth of current dollar GNP has averaged 8 per cent over the period of calculation, relative bias = +1/8 = .125. Relative dispersion is defined as dispersion (the average absolute difference between the earlier and later estimates) divided by the average absolute value of the later estimate. For example, if the preliminary estimate of the percentage change in current dollar GNP misses the first July estimate by an average absolute amount of 3 percentage points, and if the average absolute percentage change in current dollar GNP, as measured by the first July estimate, is 10 per cent, the relative dispersion = 3/10 = .30.

Part of the results of Allan Young's comprehensive study of quarterly estimates of GNP through 1971 is shown in Table 2, along with values for the same measures of reliability calculated for the more recent period covered in this study. The comparative results would seem to indicate a slight deterioration in the reliability of preliminary estimates of quarterly changes in real GNP from the 1966:1-1971:4 period to the 1972:1-1978:1 period. Considering the much wider fluctuations of growth in real GNP in the latter period, however, some decline in reliability might have been expected. That is, the deterioration in the values of relative bias and relative dispersion for preliminary estimates of growth in real GNP over the more recent period is probably not indicative of decreased reliability of techniques of preliminary estimation. Instead, the deterioration indicates that any estimation procedure performs somewhat less well under periods with relatively dramatic fluctuations compared to periods of relatively stable growth. In light of this observation, the deterioration can be considered quite small, and it can be concluded that preliminary estimates have remained reliable under a period of severe strain in the economy.[10]

Table 2
MEASURES OF REVISIONS IN QUARTERLY PERCENTAGE CHANGES OF GROSS NATIONAL PRODUCT AND REAL GROSS NATIONAL PRODUCT
(Preliminary Estimates Compared With First July Estimates)

Variable and Period	Relative Bias	Relative Dispersion
Gross National Product		
1964:1 to 1971:4 (Young)	−.06	.11
1972:1 to 1978:1	−.05	.12
Real Gross National Product		
1966:1 to 1971:4 (Young)	.05	.19
1972:1 to 1978:1	−.09	.23

10 In a study that preceded Young's, Rosanne Cole focused on the quarterly levels of GNP and its components as well as on the quarterly changes (in dollars, not per cent) in these levels. Cole found that preliminary estimates of the level of current dollar GNP over the period 1957:4-1962:4 underestimated "actual" GNP levels, as defined by the then final estimates provided by the 1965 benchmark revision of the NIP accounts, by about 2 per cent. For the period 1972:1-1978:1 covered in this article, preliminary estimates of the level of GNP have been, on the average, about 1 per cent below the latest available estimates. These latest available estimates have not all undergone a benchmark revision, however, so no conclusions as to improved reliability can be reached on the basis of this comparison.

SUMMARY AND CONCLUSIONS

Of all the measures of economic activity, GNP is the most comprehensive. Of those estimates of GNP, the preliminary quarterly estimates—available for a calendar quarter about 15 days after that quarter is over—receive the most attention. The timely character of these preliminary quarterly estimates requires, as one might suspect, some sacrifice in reliability. Data available for the three months of the quarter at the time of the preliminary estimates are often incomplete, and always subject to revision. Consequently, there is some question as to whether or not preliminary quarterly estimates of GNP are useful for making economic policy.

The six-year period from the first quarter of 1972 through the first quarter of 1978 includes a complete business cycle in which the country experienced both its most severe recession and its most severe inflation since World War II. These extreme shocks to the economy, it would seem, are a good test of how well preliminary estimates of GNP stand up under change. The findings of this study tend to parallel those of others covering earlier periods: preliminary quarterly estimates of GNP do provide a generally reliable basis for assessing recent economic developments.

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