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Forecasting and Modeling the U.S. Economy in 1986-88

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The U.S. economy turned in a mixed performance in 1986. Inflation fell to its lowest rate in more than 20 years, but output growth also slowed to a well below-average pace. A mixed performance was just what had been predicted by a forecasting model maintained by researchers at the Federal Reserve Bank of Minneapolis (Litterman 1985). Unfortunately, that model had predicted a different mix: rising inflation and above-average growth. So 1986 was clearly a bad year for the model.

The next two years may be better. To try to correct problems that seem to have contributed to its errors in 1986, we have changed the forecasting model. The new and (we hope) improved model predicts that U.S. economic performance in 1987–88 will likely be mixed again, this time with about average growth but rebounding inflation.

Growth and Inflation: On the Rebound

Last year was the fourth year of an economic expansion that has passed from a brilliant youth through an extended but somewhat disappointing middle age. The expansion's next phase, according to our forecasting model, is likely to be a reinvigorated old age. Unfortunately, though, its renewed vigor will probably rekindle inflation more forcefully than growth.

1986: A So-So Year in a So-So Expansion

The vigorous youth of this expansion was in 1983–84, when the U.S. economy began to recover from a severe recession. In those years, the inflation-adjusted gross national product (real GNP) bounced back at a 5.6 percent annual rate, faster than the 5 percent rate typical of the first two years of post–World War II expansions. Simultaneously, the inflation rate, as measured by changes in the GNP price deflator, fell by almost a third to an annual average rate of 3.6 percent.

The expansion lost much of its vitality in 1985–86. On average, both in the postwar period as a whole and in the third and fourth years after the beginning of a postwar recovery, real GNP expanded at about a 3.2 percent rate. Recent growth was slower, just 2.9 percent in 1985 and 2.2 percent in 1986. However, gains against inflation continued. The rate of inflation fell from 3.6 percent to 3.3 percent in 1985 and then, in 1986, to 2.2 percent, the lowest rate since 1964. The low 1986 inflation rate reflected oil prices, which tumbled when members of the Organization of Petroleum Exporting Countries (OPEC) could not agree on strict oil production limits.

The slowdown in growth in 1985–86 has changed the image of the current expansion. It no longer looks like a pacesetter, for it now ranks fifth among the eight postwar expansions in cumulative four-year growth. After four full years of growth, however, it has achieved longevity. Only two of the other seven expansions lasted as long as four years. And this expansion is unique in sustaining both growth and disinflation so long.

The economy's performance in 1986 alone may be best described as so-so. (See Table 1.) Its good points, besides the decline in inflation generally and consumers' energy bills particularly, include falling interest rates and a robust stock market; these no doubt helped spur the year's healthy growth in residential investment and consumer spending, especially spending for durable goods like autos. The unemployed portion of the labor force also declined a bit in 1986, 0.2 percentage point. The year's bad points, which helped slow overall growth, include deterioration in the nation's trade balance and sharp cuts in business investment and inventories. The oil price decline contributed to these negative developments, too: most of the cuts in the business structures component of fixed investment were in the domestic energy industry.

1987–88: Growth and Rising Inflation . . .

Considering its recent feebleness, can this aging expansion continue through 1987–88? Our model thinks so. Based primarily on the historical relationships among national economic variables, it forecasts that these next two years will likely bring renewed growth—but also renewed inflation. The acceleration in growth may be modest and temporary while the pickup in inflation may be sharper and more sustained.

The model bases its current forecasts on the values of about 50 U.S. economic variables in the 15 months ending in February 1987. The forecasts are generated by inserting those measures of recent economic performance in the model's equations and calculating the results. The equations are based on a combination of historical evidence about the interactions among economic variables and some assumptions about those relationships that we have required the equations to approximate.[1]

Filtering through the goods and bads of economic performance in 1986 and early 1987, the model finds evidence that somewhat faster growth lies ahead for the U.S. economy. (See Table 1.) After 2.2 percent growth in 1986, real GNP is predicted to grow, on average, more than 3 percent per year in 1987–88. This should be just enough to keep unemployment from changing much over that time. Growth is likely to strengthen temporarily, however. The model predicts that real GNP will grow nearly 4 percent in 1987 and that by the fourth quarter the unemployment rate will fall to 6.5 percent.

Rebounds in business inventories and fixed investment account for much of this projected acceleration. While most other components of real GNP grow about as fast in 1987 as in 1986, the model says, these two components will bounce back from big 1986 declines. The projected growth in business fixed investment is limited to its durable equipment component, which is expected to rise 14.8 percent in 1987 after falling 0.6 percent in 1986. Businesses are also expected to moderate their cuts in investment in structures, from 15.7 percent in 1986 to 7.8 percent in 1987.

Economic growth is predicted to slip back below average in 1988. The model forecasts that real GNP will expand closer to 2, rather than 4, percent in that year as the unemployment rate climbs back to almost 7 percent.

This decline in growth will partly reflect the ending of 1987's business investment spurt, the model predicts. Business inventory accumulation is expected to slow by the end of 1988. At the same time, the model says, business investment in structures will likely fall about 9 percent while the growth in durable equipment investment slackens to about 8 percent. As a result, total business fixed investment would drop back to a near-normal rate of growth in 1988.

Slower growth in investment by consumers could also restrain growth in 1988. The model projects a decline in residential investment and hardly any growth in consumer spending for durable goods (which is officially counted as consumption but can also be considered as investment in long-lasting household capital items, such as cars and appliances).

Continued real GNP growth will be accompanied by accelerating inflation in 1987–88, the model says. From a low point in 1986, growth in the GNP price deflator is projected to nearly double to its postwar average rate in 1987 and then rise further in 1988.

. . . Maybe

Of course, economic forecasts are always off at least a bit and often by a fair amount. Our model's forecast is no exception. This model can make errors for at least two basic reasons. One is that the model is not perfect; it does not capture all the available information about the economy or use the information it does have in the most effective way. The other is that some important information is simply not available when a forecast must be made. This introduces an irreducible element of uncertainty, or luck, in forecasting, and bad luck can produce big errors.

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[1]For a general discussion of our procedures for combining data and assumptions to produce what is known as a Bayesian vector autoregression (BVAR) model, see Doan, Litterman, and Sims 1984 and Todd 1984.

Table 1

The U.S. Economic Outlook in Perspective

Indicator	Actual 1986	Model Forecast 1987	Model Forecast 1988	Average Since WWII
Annual Growth Rates (4th Qtr. % Changes From Year Earlier)				
Real Gross National Product	2.2%	3.8%	2.3%	3.2%
Consumer Spending	4.0	4.4	2.9	3.4
Durable Goods	9.9	6.3	.6	4.8
Nondurable Goods and Services	2.9	4.0	3.4	3.2
Investment	-2.2	13.7	.9	3.0
Business Fixed	-5.4	8.4	3.8	3.3
Residential	9.8	9.2	-1.7	2.8
Government Purchases	3.3	-2.6	3.2	3.8
Gross National Product Deflator	2.2	4.1	5.3	4.2
4th Quarter Levels				
Change in Business Inventories (bils. of 1982 $)	-11.6 bil.	19.4 bil.	11.2 bil.	—
Net Exports (bils. of 1982 $) (Exports less Imports)	-155.5 bil.	-187.9 bil.	-203.4 bil.	—
Civilian Unemployment Rate (Unemployment as a % of the Labor Force)	6.8%	6.5%	6.9%	5.7%

Sources of basic data: U.S. Departments of Commerce and Labor

An example of some available information that the model may be slighting this year is the federal tax reform taking effect in 1987. The model has no tax variables, so even though we know about major changes in the tax system, we have no simple, direct way to force the model to react to them.[2] That does not mean, however, that the scheduled tax changes have not affected the model's forecast. It means that those changes affect the forecast indirectly, through their impacts on such model variables as stock prices and consumer spending.

The new tax law is only one example of the special factors in the 1987–88 outlook that our model reflects somewhat indirectly and, thus, probably somewhat inaccurately. The U.S. economy has been experiencing a string of fiscal and trade deficits unprecedented in the postwar years, possibly making the historical relationships among the model's variables outdated as guides to the future. Besides that, in 1985 and 1986 rapid money supply growth was combined with moderate and declining growth in nominal GNP, which implies the sharpest decline in monetary velocity in the postwar period—and a lot of uncertainty. If this pattern is related to falling interest rates and financial deregulation, will it persist in 1987 if interest rates stabilize and consumers complete their adjustments to the new financial environment? Or will the more typical pattern—of inflation and growth in nominal GNP running

[2]For an example of a direct but not simple way to analyze specific economic uncertainties, the possible effects of an oil price shock in 1987, see Appendix A.

parallel to monetary growth—reassert itself? The model, again, bases its forecasts partly on historical patterns and so gives at least some weight to the typical result, but is that appropriate? Other unusual uncertainties in the outlook include a possible revival of OPEC price-setting in the oil market, the ability of foreign debtors to meet their payments, adjustments here and abroad to the sharp decline in the U.S. dollar, the possibility of rising protectionism worldwide, the resilience of beleaguered sectors of the economy such as agriculture and mining, and the ability of consumers to meet debt payments and simultaneously expand their purchases.

We should emphasize, however, that uncertainty in the economic outlook is normal. Although it may sometimes seem to be heightened by special factors, the course of the economy is always affected by special factors and unanticipated events. Even the best possible model—one that optimally used all available information—would explain only a portion of the variation in the economy over the postwar period; each year bad luck would push its forecasts off for one unforeseeable reason or another. Models like ours on average make even larger errors than that optimal model would. To measure the average degree of uncertainty this fact creates, our model computes the size of its own typical forecasting errors over the postwar period. We then can use these to compute the ranges of normal uncertainty surrounding the model's current forecast. (Here by *normal* we mean a range of values that, based on the model's previous forecasts, has a 70 percent chance of including the actual outcome.) These ranges of uncertainty (or *confidence bands*) are displayed around the model's output and inflation forecasts in Charts 1 and 2. They imply that, for example, while real GNP will most likely grow at about a 4 percent rate throughout 1987, growth rates as great as 9 percent or as small as 1 percent would not be unusual in any quarter.

Charts 1 and 2

The Model's Hedged View of U.S. Output and Inflation in 1987-88

Predicted Quarterly Percentage Changes at an Annual Rate, With 70 Percent Confidence Bands*

Chart 1 **Growth in Real GNP**

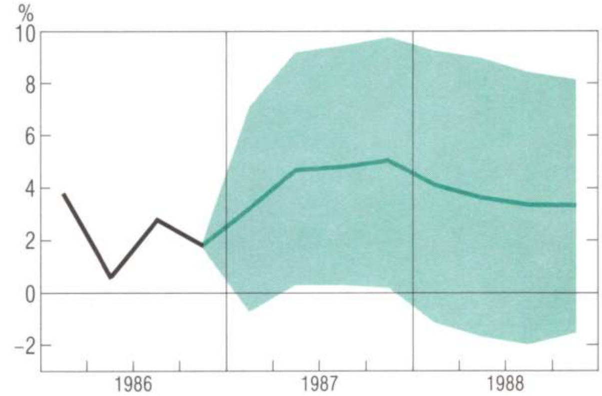
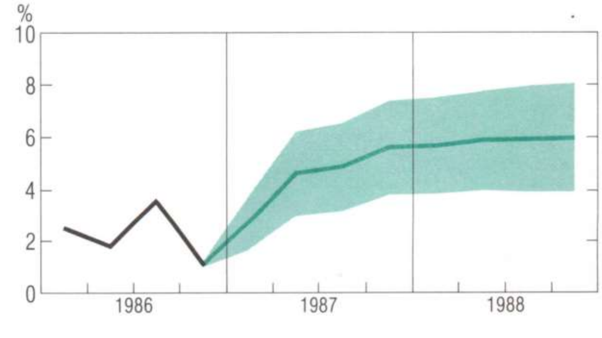


Chart 2 **Growth in the GNP Deflator**



*Most likely growth path for each variable surrounded by a range within which it is likely to fall 70 percent of the time, based on 1,000 simulations.

Source of basic data: U.S. Department of Commerce

The Model: Also on the Rebound?

The possibility of large forecast errors is, unfortunately, not just hypothetical. A forecast of economic performance in 1986, made by last year's version of our model, turned out to be off target. Furthermore, an analysis of its errors suggests that they are not likely due just to the kind of unavoidable bad luck that would afflict even optimal models. Instead the errors seem to be partly the result of systematic flaws in the model. Some of the errors, in fact, point to particular flaws and suggest changes to correct them. Having made some of those changes, we think they give the model a better chance of hitting the target this year.

The 1986 Errors: More Than Bad Luck

Last year the model predicted strong economic growth and rising inflation in 1986 (Litterman 1985). It was wrong on both counts. Instead of growing the forecasted 5.6 percent, real GNP grew only about 2 percent. Instead of dropping one full percentage point, the unemployment rate hardly changed. And instead of speeding up one full percentage point, the inflation rate slowed about that much. Clearly, last year's forecast significantly mischaracterized the main qualitative features of the economy's performance.

The errors in last year's forecast were significant quantitatively, too, and that suggests that they are due to flaws in the model as well as bad luck. According to the confidence bands around last year's forecast, the model put fairly low probabilities on errors as big as those it actually made (Litterman 1985, p. 3). Real GNP growth and the unemployment rate were near the edges of their confidence bands in 1986, while the deflator was below its band. Conceivably, last year's forecast still may have been accurate, based on available information; the large errors may have just resulted from an unlucky combination of unpredictable shocks to the economy. But the model itself says, through these confidence bands, that bad luck alone does not usually produce errors as big as it made in 1986.

Besides that, many other forecasters managed to have much better luck. Of the 50 forecasts reported in the December 1985 *Blue Chip Economic Indicators*, 47 put 1986 growth slower than the model, and 24 of these also put the inflation rate equal to or slower than the model. On average, the December 1985 Blue Chip panel expected slightly below-average real GNP growth and nearly steady unemployment and inflation in 1986—qualitatively, a much better view of what was ahead.

Furthermore, detailed examination of the model's GNP forecast errors in 1986 reveals that they were not spread throughout the forecast. The model seems to have fairly accurately anticipated consumers' behavior, the largest contributor to output growth. (See Table 2.) Qualitatively, the model was correct. It foresaw that consumer spending would grow at an above-average rate, would be led by very strong growth in spending on durable goods, and would be accompanied by very strong growth in residential investment. Quantitatively, the model didn't do too badly with consumer behavior, either. Slower-than-forecasted growth in spending for services and nondurable goods held total consumer spending growth to 4 percent, half a percentage point below the model's prediction. This overprediction was partly offset by the model's underprediction of residential investment, which grew about 10 percent instead of about 8.

Where the model really missed was in business fixed investment, business inventories, and net exports. Altogether, the model overpredicted these three GNP components by about \$150 billion.[3] That accounts for more than the model's total \$125 billion, or 3.4 percentage point, error in forecasting 1986 growth in real GNP.

The model's most significant error was in business fixed investment. This component was expected to grow 10.1 percent, more than three times its historical average rate of 3.3 percent. Instead it fell sharply, 5.4 percent. This error, the equivalent of almost \$75 billion and two percentage points of growth, is due partly to unforeseeable factors and partly to factors foreseen in late 1985 but not directly incorporated into the model. Few people expected the dramatic oil price collapse of 1986, which severely curtailed oil exploration in the United States. That accounts for much of the weakness in business fixed investment, especially investment in structures like oil rigs. Two other factors—less surprising to some, but not directly affecting the model's forecast—were low capacity utilization rates at U.S. manufacturing facilities and signs of weakness (related to rising vacancy rates and expected tax law changes) in the commercial real estate markets.

About one percentage point of the model's total error was in the forecast of business inventories. The model had predicted an inventory accumulation of about \$24 billion in the fourth quarter of 1986. Instead, inventories fell \$11.6 billion. The model's error partly reflects the fact that inventories, always a volatile, hard-to-predict component of GNP, were further destabilized by off-again, on-again auto sales incentives. The gyrations of auto sales and inventories were particularly severe in the months just before November 1985, when the model's 1986 forecast was computed. The model had little historical basis for interpreting these gyrations and may have been misled by them into a prediction of strong inventory accumulation.

However, this error may also have been related to the surprising deterioration in the nation's trade deficit. The rate of inventory accumulation lagged the growth of sales in 1986. Although this may in part be due to low inflation and high real interest rates, the Congressional Budget Office (CBO 1987, p. 35) points out that the "downtrend in the inventory-to-sales ratio could also have been caused in part by the foreign trade deficit, since manufacturers' inventories declined over the year even as wholesale and retail trade inventories were being built up."

[3]For comparability, all the dollar values we mention have been adjusted for inflation; they reflect the price level in 1982.

Aside from that possibility, growth in the trade deficit was itself a component of the model's 1986 forecast error. The model projected that the gap between exports and imports would shrink about 13 percent in 1986; instead, it expanded almost 18 percent. This error is the equivalent of about 1 percentage point of the model's total 3.4 percentage point overprediction of growth in 1986.

Problems in measuring the foreign exchange value of the U.S. dollar may have contributed to the trade deficit error. The model used the U.S. Commerce Department's index of exchange rates, which omits many newly industrialized countries. In general, these countries are becoming increasingly important to U.S. trade, and their currencies have not appreciated as fast as those in the Commerce Department index. That index, then, may have exaggerated the decline of the dollar in 1985, leading the model to expect improvement rather than deterioration in the trade deficit.

The model's error in the 1986 inflation rate also seems to have resulted from both simple surprises and potentially correctable measurement problems. The biggest surprise, of course, was the sharp decline in energy prices. The impact of this decline on inflation generally is clear when two measures of consumer prices are compared: the standard consumer price index (CPI) and the stripped CPI, which omits the prices of some particularly volatile items—food consumed at home, used cars, and energy. Growth in the standard CPI, as in the GNP deflator, slowed significantly in 1986. Growth in the stripped CPI, however, did not; this index rose a bit more than 4 percent in 1986, about as much as in the previous two years. This was also almost exactly as much as the model had predicted the overall GNP deflator to rise.

Problems in measuring the money supply may have contributed to the model's inflation error as well. The primary monetary variable in the model was the traditional measure of liquid assets, M1. It consists mainly of currency and money in accounts with liberal checkwriting privileges. Over most of the postwar period, growth in M1 has been roughly proportional to subsequent inflation, perhaps because M1 has consisted mainly of consumers' easily spendable funds. In the last decade, however, financial innovation and deregulation have let consumers earn interest on many accounts in M1. As a result, M1 accounts are much more attractive as investments than they used to be, and consumers are holding a larger share of their savings in them. However, these savings tend to shift in and out of M1 in response to changes in the difference between interest rates on accounts in and out of M1. This is a new source of variability in M1, one that may cause it to grow rapidly sometimes for reasons not closely related to subsequent inflation. To the extent this was true in 1985, the model was misled by its reliance on M1 as a measure of money.

Finally, the model's 1986 inflation error may, like its trade deficit error, be due to the problem of measuring the dollar's exchange rate. A falling dollar has typically been associated with rising import prices and accelerating inflation. Nonoil import prices did rise in 1986, but not as much as the Commerce Department dollar index fell. If this index exaggerated the effects of the dollar's decline, it helped cause the model's inflation error.

The Result: A Revised Model . . .

Errors due to bad luck cannot be avoided—but others might be. Much of our model's error in 1986 seems to be due to problems with the particular variables it includes. That has led to some changes in variables which should improve the model's ability to forecast at least the major economic indicators—real GNP, unemployment, and inflation.[4]

The variables in the model are grouped into a core sector and seven subsidiary sectors (representing major types of economic activity: production, labor, consumption, government, international trade, financial markets, and prices). (See Litterman 1984, p. 7.) The core sector is a self-contained model of those variables considered the most important and informative in macroeconomic forecasting (measures of things like output, inflation, interest rates, and the money supply). The other sectors are semi-independent models; they each include some variables particular to the sector as well as some from the core and, sometimes, from other sectors.

Three variables in the model's core sector have been changed since last year's forecast. One variable—total nonfinancial debt—has simply been deleted from the model. This is because financial deregulation and the wave of debt-financed corporate restructurings in recent years seem to have changed the relationships between debt and other economic variables. In short, the measure of total nonfinancial debt no longer conveys useful information about the economy's future performance.

[4]Other changes have been made in the model as well, particularly changes in the technical methods for using the selected variables. This type of change is generally prompted more by ongoing research into forecasting methods than by any particular forecasting error. For a summary of recent technical changes, see Appendix B.

Another core variable—the foreign exchange value of the U.S. dollar—has been revised. The old measure of this variable—again, the Commerce Department's dollar index—is based on a set of weights that reflect world trade patterns among the large developed economies in 1972–76. Because this index gives no weight to the currencies of many countries of growing importance to U.S. trade (Korea and Taiwan, for example), it now seems too narrowly based to accurately measure the impact of recent (and future) changes in the dollar's value. By focusing much of its weight on Germany and Japan, that is, the index may have exaggerated the decline of the dollar since 1985 and so caused the model to overpredict inflation and underpredict the trade deficit.

Although several broader indexes have been proposed as better measures of the dollar's foreign exchange value, the most convenient for us is the Dallas Federal Reserve Bank's index (not adjusted for inflation in the covered countries). (See Cox 1986.) This series is available monthly back to January 1976. We are keeping the Commerce Department series for earlier years, when U.S. trade was more concentrated among the countries it covers.

So far the change in the exchange rate variable is most evident in the model's forecasts for inflation: they are markedly lower with the Dallas index than with the Commerce index. The change has also modestly affected the model's import and export equations, resulting in slightly larger trade deficit forecasts.

A third change in the core sector is the substitution of the monetary base for M1 as the model's money supply variable. The monetary base consists mainly of currency and the reserves of depository institutions; unlike M1, it does not include funds in accounts with liberal checkwriting privileges. M1 has not been discarded, however; it is now a subsidiary variable predicted by an equation in the model's financial sector, as the monetary base used to be. In addition, the measure of the monetary base in the model has been changed from a series maintained by the St. Louis Federal Reserve Bank to one maintained by the Federal Reserve Board of Governors.[5] The reversal in the positions of M1 and the monetary base in the model is supported by recent evidence that the base's relationship to the economy has been more stable than M1's (Christiano 1986). This change seems to have reduced the model's forecasts of both inflation and growth from what they would have been with the old model.

One variable not in the model's core sector has been changed as well. The inventories of durable goods variable in the production sector is now divided into auto and nonauto components. This lets us use more directly the monthly and even more frequently available data on auto sales and inventories. It also lets us see more directly the effects on the model of typical—or unusual—volatility in auto sales and inventories.

. . . And Better Forecasts?

Though still far from perfect, the revised forecasting model is probably better than its predecessor. At least, the changes made to the model seem sensible: Treating auto inventories separately and revising the measures of money and the dollar's foreign exchange value would seem to help produce equations that represent stable and reliable relationships among economic variables.

Confidence in the revised model is strengthened by its apparent better ability to predict real GNP, unemployment, and inflation. To test this, we estimated the relationships among the new model's variables through October 1985, just before the old model forecasted 1986; in effect, that is, we gave the new model all the information the old model could have had for that forecast. We then asked this version of the new model to predict 1986. The results, shown in Table 2, indicate that the revised model would have come closer to the actual values of the aggregate measures of economic activity. The real GNP forecast would have been only slightly better, but the model's errors in forecasting unemployment and inflation would have been cut in half.

The revised model also looks better in relation to other forecasters: in general its 1987 forecast is more in the mainstream than the old model's 1986 forecast was. Both the current and the previous forecasts of inflation one year ahead match the average of the dozens of contemporaneous forecasts published in the *Blue Chip Economic Indicators* (Blue Chip 1987b, 1985). However, the previous forecast of the unemployment rate one year ahead was 0.7 percentage point below the Blue Chip average, and only one Blue Chip panelist forecasted a rate that low. The previous real GNP growth forecast was 1.6 percentage points above the Blue Chip average and was matched or exceeded by only three panelists. The model's current forecasts of these two variables are much less atypical. The unemployment rate prediction for 1987 is only 0.3 percentage point below the Blue Chip average and equals or exceeds the

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[5]We start with the Board's raw series, unadjusted for either seasonal fluctuations or reserve requirement changes. We deseasonalize that series as described in Amirizadeh 1985, but do not adjust for reserve requirements.

Table 2
A Second Look at 1986

	Indicator	Old 1986 Forecast	Actual 1986	New 1986 Forecast*
Aggregates	**Annual Growth Rates** (4th Qtr. % Changes From Year Earlier)			
	Real GNP	5.6%	2.2%	5.3%
	GNP Deflator	4.3	2.2	3.3
	4th Quarter Level			
	Civilian Unemployment Rate (Unemployment as a % of the Labor Force)	6.0	6.8	6.4
Components	**Annual Growth Rates** (4th Qtr. % Changes From Year Earlier)			
	Consumer Spending	4.5%	4.0%	5.1%
	Durable Goods	9.7	9.9	12.3
	Nondurable Goods and Services	3.5	2.9	3.8
	Investment	13.0	-2.2	21.9
	Business Fixed	10.1	-5.4	17.0
	Residential	8.2	9.8	17.9
	Government Purchases	1.9	3.3	-5.0
	4th Quarter Levels (bils. of 1982 $)			
	Change in Business Inventories	24.4 bil.	−11.6 bil.	31.0 bil.
	Net Exports (Exports less Imports)	-115.1	-155.5	-166.1

*Based on revised data (available October 1985) and model.
Sources: Litterman 1985, U.S. Departments of Commerce and Labor

rates predicted by more than a dozen panelists. Similarly, the current real GNP growth forecast is only 0.7 percentage point above the Blue Chip average and is matched or exceeded by the forecasts of an even dozen panelists.

Of course, closely matching other published forecasts does not necessarily make our model's current forecast accurate. Last year, in fact, most other forecasters were also wrong. Besides that, one distinctive feature of our model's forecast is its independence of the human guesswork often built into other forecasts. However, in recent years the historical relationships among economic variables that our model relies on appear to be changing more rapidly than ever before in the postwar period. This has required changes in the model's equations to try to objectively capture the new relationships, a process that many other forecasters supplement with subjective modification of the model's forecasts. To the extent that their subjective forecast adjustments do take account of the new relationships, our closer correspondence to their forecasts suggests that our model is capturing some of the new relationships, too.

We are well aware, however, that both our model and its current forecasts are far from optimal. We have had neither the insight nor the time to devise and test solutions for all of the problems suggested by the model's recent forecasting errors. Even the changes we have made should be viewed as provisional efforts in an ongoing research program. More efforts may be needed to improve the model's performance with regard to some of the individual components of real GNP. Table 2 shows that, notwithstanding its more accurate 1986 forecast of aggregate GNP, the new model would have had even larger errors than the old model in predicting many of its components.

Furthermore, the new model's 1987 forecasts of these components contradict the patterns expected by a majority of the Blue Chip panelists this year (Blue Chip 1987a, p. 8). The panelists say that the most favorable influence on economic growth in 1987 will be a "sharply lower dollar," which will "diminish [the] trade deficit." The model predicts instead that the trade deficit will widen significantly in 1987. The model finds strength not in trade, but in a boomlet in investment and continued expansion of consumption. Again, the Blue Chip panel disagrees, citing as the two least favorable influences on growth in 1987 the "negative effects of tax reform," which "reduces investment incentives," and "excessively high" consumer debt, which dampens growth in consumption.

In Conclusion: A Defense of Model-Based Forecasting

So, our model made significant errors in forecasting 1986, its defects have not all been corrected, and its 1987–88 forecasts, especially of GNP components, could easily turn out to be way off. Nonetheless, we think that these forecasts deserve consideration and that our forecasting procedure—presenting the untouched predictions of an explicit, self-contained statistical model involving the interrelationships of many variables—is worthy of further research.

Explicit, self-contained forecasting models can provide useful information that is rarely available from other forecasting procedures. An explicit model is one completely written down in a mathematically precise form, such as a computer program. Writing down such a model makes all the assumptions and knowledge built into the model unambiguous, so that they can be criticized and improved on by anyone. This alone is an advantage. But if a model is also self-contained—capable of forecasting all of its variables internally, without human tinkering—then it has two further advantages. It can generate meaningful and internally consistent measures of the uncertainty surrounding its forecasts. (See Todd 1984 and Litterman and Supel 1983 for more on this.) And it can provide an independent, unique perspective on the economy's future, one relatively free of the presumptions and biases that often influence human forecasters.

One way to build an explicit, self-contained model is to predict each variable by an equation based just on the variable's own past values. We use such *univariate* models to set a standard of accuracy. We then try to meet that standard while also capturing the predictable linkages among economic variables in a *multivariate* model. Since economic theory suggests that economic variables are highly interactive, the forecasts of a good multivariate model should, in principle, be better than those of a bunch of univariate models of the same variables. (Admittedly, constructing a good multivariate model is, in practice, difficult. Our procedure is described in Doan, Litterman, and Sims 1984 and Todd 1984.) Multivariate models have one other advantage. They can answer at least some kinds of questions about the effects that movements in one economic variable will have on other economic variables. This is obviously impossible with a univariate model.

The particular type of explicit, self-contained, multivariate model that we work with—the so-called Bayesian vector autoregression, or BVAR, model—shows special promise. The forecasting track record of such models is respectable despite the errors in 1986. From early 1980 to early 1985, for example, a set of BVAR models maintained by Litterman (1986) predicted U.S. real GNP and unemployment one year ahead at least as well as some of the nation's leading forecasting firms. Furthermore, extensive testing of several BVAR models indicates that this type of model forecasts about as accurately as, and often more accurately than, the best univariate models. Few other multivariate approaches have documented this degree of accuracy. Finally, BVAR models are likely to continue to improve—and not just because they are explicit models open to future criticism. Many excellent ideas for refining them are already being tested.

Appendix A
Simulating an Oil Price Shock

From time to time in the past 20 years, sharp changes in crude oil prices have seemed to have a major impact on the aggregate U.S. economy. (See, for example, Hamilton 1983.) While some impact might be expected based on conceptual grounds, the size of the impact is still an open empirical issue. Simulations with the national forecasting model maintained by researchers at the Minneapolis Fed suggest that the impact has shrunk over time, so that oil price changes can be expected to affect the U.S. economy less today than they did in the 1970s.

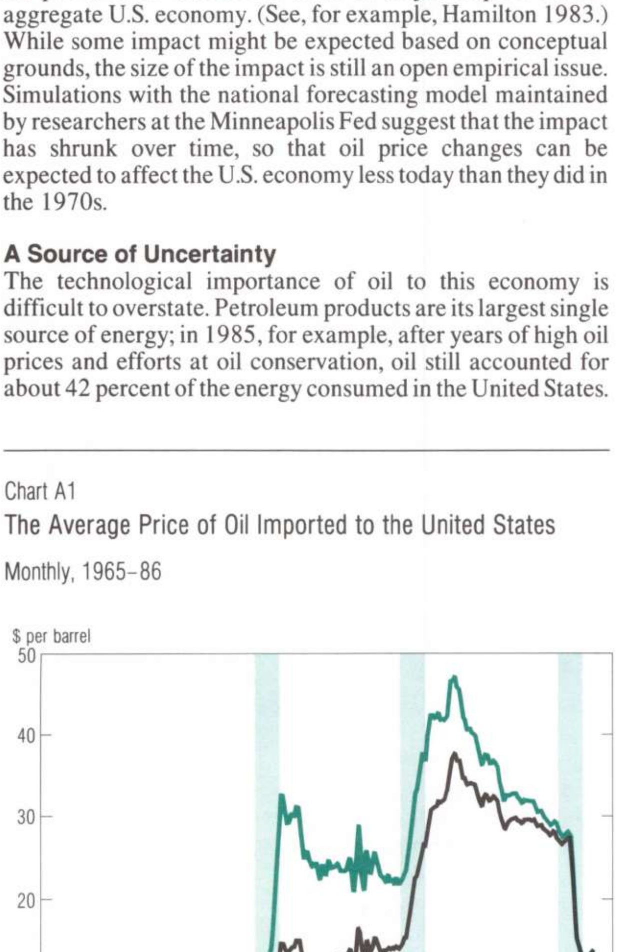
A Source of Uncertainty

The technological importance of oil to this economy is difficult to overstate. Petroleum products are its largest single source of energy; in 1985, for example, after years of high oil prices and efforts at oil conservation, oil still accounted for about 42 percent of the energy consumed in the United States.

Chart A1

The Average Price of Oil Imported to the United States

Monthly, 1965–86



Note: The shaded areas are, roughly, periods of oil price shocks.
Source: U.S. Department of Commerce

Obviously, then, sudden large changes (or *shocks*) in the price of oil could have strong negative effects on the course of the economy. A sharp rise in this price would, in the short run, increase the real costs of most industries and reduce the real incomes of most consumers, which would in turn reduce overall growth. In the longer run, these effects may be at least partially offset by capital investment in conservation and alternative energy sources (insulated houses, fuel-efficient airplanes, and coal-fired power plants, for example)—but that can take years. In the meantime, the depressing effects of an oil price rise would likely persist. A sudden fall in the price of oil, while beneficial to consumers, also could have serious negative effects on growth. This has been clear in the last two years, as rapid declines in oil prices have dramatically curtailed U.S. oil exploration and production and generally slowed the growth of regional economies closely tied to the oil industry.

Historically, the negative effects of sudden changes in the price of oil have probably been exacerbated by the fact that such changes have been unexpected. As Chart A1 shows, over most of the past 20 years, crude oil prices have moved neither smoothly nor predictably. Instead, they have moved dramatically at least three times—after the 1973 oil embargo, the 1979 revolution in Iran, and the 1985 collapse of the OPEC pricing structure. And since 1973, they have been fluctuating much more between dramatic events, too.

All of this makes forecasting oil prices a highly uncertain activity for anyone. It is especially difficult for our national forecasting model because the price of oil is determined by international factors largely outside its scope. In fact, this price is not one of the variables the model routinely tracks. However, because the model does provide a summary of the responses of its variables to random shocks, it can also provide some rough idea of the effects of an oil price shock, or a sequence of shocks, on the national economy. This can be done by associating unexpected changes in the model's variables with unexpected changes in the price of oil.

Defining an Oil Price Shock

As Sims (1986) points out, any attempt at calculating the effects of any shock necessarily involves some *identifying*, or defining, assumptions that make the notion of the particular shock precise. Although these assumptions can be formalized in several ways, they are all cumbersome for models as large as ours. Instead of using these methods, therefore, we have simply looked at changes in closely related variables of the

Behind the Simulation of an Oil Price Shock

Table A1

Changes Accompanying a Sudden 30% Oil Price Increase

Model Variables	Changes*
Price Sector	
Index of Spot Market Prices for Raw Industrials	4.3%
Energy Component of the Consumer Price Index	3.6
Producer Price Index	1.7
Price Deflator of the Gross National Product	.5
Export/Import Price Ratio	-3.1
Financial Markets Sector	
10-Year U.S. Government Bond Rate	23 basis points
3-Month U.S. Treasury Bill Rate	20
Federal Funds Rate	17
Standard & Poor's 500 Common Stock Price Index	-2.1%

*Average changes in oil price-related variables during months in 1965–85 in which the average price of oil imported to the U.S. changed more than 10%.

Sources: U.S. Departments of Labor and Commerce, Federal Reserve Board of Governors, Standard & Poor's Corporation

Chart A2

A Sequence of Monthly Oil Price Increases

Percentage Changes in the Price of Oil Imported to the U.S. After the 1973 Oil Embargo

Source: U.S. Department of Commerce

model during periods when the oil price changed drastically—specifically, changes in some price indices and financial market variables during the months of 1965–85 in which the average price of oil imports moved more than 10 percent. After correcting for the sign of the oil price changes, we averaged the related changes to produce a definition of an oil price shock. Our definition implies that an unexpected extremely large (30 percent) increase in the price of oil would be accompanied by the changes in price and financial market variables displayed in Table A1.

Of course, this definition of an oil price shock assumes that a sudden change in the price of oil affects the economy initially only through relative prices and financial market variables.* Real quantities, such as the gross national product (GNP), are assumed to be affected only with a lag, as the effects of changes in prices and interest rates work their way through the economy.

One way to simulate an oil price shock in our model is to simply apply the changes of Table A1 to the first month of our forecast. However, historically oil price shocks have not been limited to just one month, and cumulatively they have involved an oil price increase greater than 30 percent. So we instead apply a sequence of monthly shocks that about matches a sequence the economy actually experienced, during late 1973 and early 1974, after the oil embargo. Over that period, the average price of imported oil increased a total of 109.5 percent, through a sequence of monthly increases, shown in Chart A2. For our simulation, we assume that oil prices follow this sequence exactly, but starting in April 1987. We adjust the changes in the model variables that accompanied the 30 percent one-time oil price increase (Table A1) to reflect instead the oil price increase in each individual month of the sequence. This adjusted series of changes is then applied to the model.

Surprising Effects . . .

The results of this simulation are somewhat surprising. (See Table A2 and Charts A3–A5.) Qualitatively, the model's predictions are exactly what one would expect in the face of rapidly escalating oil prices: falling production accompanied by rising inflation and unemployment. But quantitatively, some of the effects are quite small. For real output growth, hardly any effect is predicted in 1987 and less than a percentage point loss in 1988. By contrast, the annual growth rate of real GNP fell more than 5 percentage points between 1973 and 1974 (from 5.1 percent to −0.5 percent). The effect of the oil price shock on the unemployment rate is relatively small, too, but closer to the 1973–74 experience. The model predicts virtually no effect in 1987 and a rise of only 0.7 percentage point in 1988—the same amount the unemployment rate increased between 1973 and 1974.

* A sudden change in the price of oil is also likely to have a big impact on the foreign exchange value of the dollar. Due to recent measurement problems with this variable, however, we have excluded it from this experiment.

Table A2

The Projected Annual Effects of an Oil Price Shock

Variables	1987 Without Shock*	1987 With Shock	1988 Without Shock*	1988 With Shock	% Point Difference (Due to Shock) 1987	% Point Difference (Due to Shock) 1988
Annual Growth Rates						
Real GNP	3.00%	2.85%	3.09%	2.47%	- .15	- .62
GNP Deflator	3.09	4.42	5.10	7.17	+1.33	+2.07
Annual Level						
Unemployment as a % of the Labor Force	6.60	6.65	6.67	7.38	+ .05	+ .71

*Note that these projections are in terms of annual averages rather than fourth quarter levels, so they do not match those in the preceding paper.

Sources of basic data: U.S. Departments of Commerce and Labor

In striking contrast to these real series, the predicted effect of the oil price shock on inflation is immediate and quite large. The model says growth in the GNP deflator would be increased 1.3 percentage points in 1987 and 2.1 percentage points in 1988. These increases are very close to the 1.8 and 2.2 percentage point increases experienced in 1973 and 1974.

. . . But Reasonable

So, on the whole, the model's simulation of an oil price shock suggests that while such a shock would probably produce sharp increases in the inflation rate, its real output effects would likely be much smaller than those experienced during the 1973–74 oil crisis. While at first glance this result may seem curious, it makes sense from both a historical and an economic point of view.

Chart A4 demonstrates that the model does not expect the oil price shock to permanently affect inflation. Instead, it expects the inflation rate to rapidly return to what it would have been without the shock. This predicted tendency for a rapid surge in inflation to be quickly reversed probably reflects a similar tendency in the historical path of inflation (and oil prices) during the late 1970s and 1980s. The experience of the last two years also suggests that the model's projection of only slightly reduced growth after an oil price shock is reasonable. The average price of oil fell about 60 percent between 1984 and 1986, yet real GNP growth over that period averaged an annual rate of only about 2.5 percent. These figures do not suggest that a doubling of oil prices would likely have the same effect on the economy as it did in 1973–74. They instead suggest that economic growth in the United States has become less sensitive to world oil price changes. Since apparently only a very small pickup in economic growth has been associated with such a large drop in oil prices, a large reduction in growth would not likely be associated with a price rise of roughly that size.

There are several reasons why the impact of an oil price shock on economic growth might be smaller today than in 1973–74. One is that the recovery of the economy from the 1973–74 shock was hampered by some poorly conceived policy actions that have since been either dismantled or substantially modified (MacAvoy 1983). Among these are price controls on domestic oil supplies that encouraged domestic consumption yet discouraged domestic production; an entitlements program that encouraged crude oil importation; and stringent controls on domestic supplies of natural gas that discouraged substitution of natural gas for oil. More important, the higher oil prices since the late 1970s have resulted in widespread substitution of funds from consumption of oil to investment in energy-saving capital (things like electronic thermostats and assembly lines for manufacturing compact cars). Since this capital depreciates only slowly, most of it is still in place today and available to reduce oil demand when the price of oil is high.

Charts A3–A5

The Projected Monthly Effects of an Oil Price Shock

Actual and Projected Without a Shock
Projected With a Shock

Chart A3 **Real GNP Growth**
(Monthly Changes at an Annual Rate)

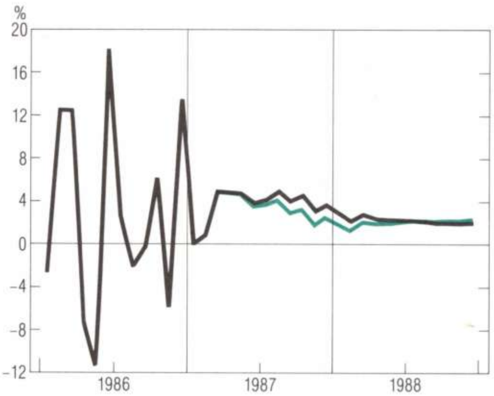


Chart A4 **GNP Deflator Growth**
(Monthly Changes at an Annual Rate)

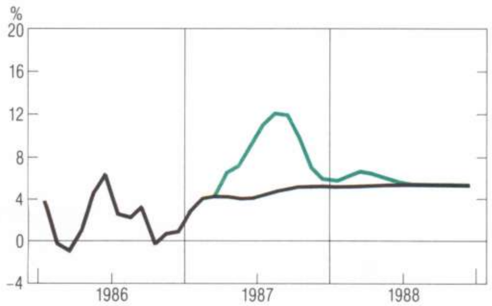
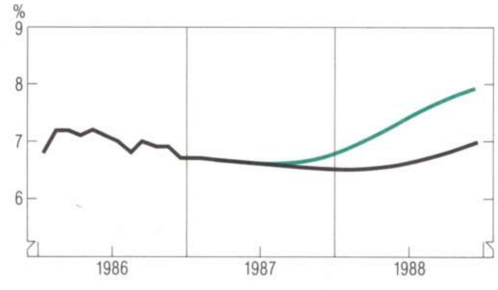


Chart A5 **Unemployment as a % of the Labor Force** (Monthly Levels)



Sources of basic data: U.S. Departments of Commerce and Labor

Appendix B
Technical Changes in the Forecasting Model

The Bayesian vector autoregression (BVAR) methods used to construct the national models maintained by Minneapolis Fed researchers have been summarized by Doan, Litterman, and Sims (1984) and Todd (1984). The main features of the model used to make last year's forecast have also been summarized, by Litterman (1984) and Amirizadeh (1985). Since that forecast was published, the model has been revised in response to its systematic pattern of forecast errors. Besides the changes in the model's variables, discussed in the preceding paper, some more technical changes have been made. These are partly motivated by the model's errors, but primarily by ongoing research on BVAR models.

Hyperparameters

One change has been to reduce the number of Bayesian hyperparameters in the model. Previously, each of the model's eight sectors, including the core, had its own independently selected set of hyperparameters. Now the model has just one basic set of hyperparameters for all sectors. This smaller number of independent hyperparameters can more reliably be chosen by the amount of postwar data available.

Two of the model's sectors—price and production—have a special modification of the basic set of hyperparameters. This is because out-of-sample forecasting experiments indicate that these sectors will not forecast as well if all the hyperparameter values that are optimal for the other sectors are imposed on them.

The price sector differs from the other sectors primarily in how the sum-of-coefficients restriction is imposed on its equations. This restriction takes the form $\Sigma_{k>0} a_{ijk} = \delta_{ij} + v_{ij}$, where a_{ijk} is the coefficient on the kth lag of variable j in equation i, $\delta_{ij} = 1$ if $i=j$ and 0 otherwise, and v_{ij} is a mean zero normal random variable. That is, sums of coefficients are about one on own lags and about zero on other lags.

Previously, the weight on this approximate prior restriction was the same for all variables. In our modification, the weight on this restriction is reduced for all variables in the model's price sector and the producer price index in its production sector.

This modification was motivated by the results of Miller and Roberds (forthcoming), who got better forecasts when they loosened the sum-of-coefficients constraints on nominal variables. In our model, the modification produces less explosive forecasts of the price variables.

Estimation, Interpolation, and Uncertainty

Changes in the hyperparameters have necessarily led to other changes in the model. Since hyperparameters influence how the historical data are converted into estimates of the model's coefficients, those coefficients have been changed, too. Also affected are the weights used to impose the model's adding-up constraints for the forecasted components of the output and inflation variables.

Changes have been made as well in the way the model uses monthly and submonthly data related to its variables. In both the old and the new models, such data are used to interpolate the monthly values of variables only officially measured quarterly. Many small refinements to these interpolation equations have been made over the past year.

One change has also been made in how the model computes confidence bands for its forecasts. In both the old and the new models, the most recently estimated coefficients are held constant in performing these simulations; the only random influences are the disturbance vectors added to the model's equations. These used to be drawn from a mean zero normal distribution with a covariance matrix estimated from the model's fitted residuals since January 1962. Now they are drawn, randomly and with replacement, from a collection of the model's one-step-ahead forecast error vectors over that period. The new procedure improves on the old in two ways. Though it still underestimates uncertainty by treating the model's coefficients as known, it partially compensates by computing wider variances (by basing them on one-step-ahead forecast errors rather than fitted residuals). And it allows for nonnormality in the model's disturbances, which is appropriate because the incidence of extreme equation errors is higher for this model than a normal distribution would predict.

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