Gross National Product at Full Employment

By John B. Penson, Jr., and Kerry Webb

Measures of gross national product (GNP) at full employment can be valuable in estimating the budget associated with the full employment of the economy's resources and in shaping policies to reduce the amount of slack in the economy. Traditionally, GNP at full employment has been viewed as "the aggregate supply capability of an economy, or the amount of output that could be expected at full employment."[1] Early estimates of "potential GNP," as it is commonly referred to, reflected the level of GNP associated with a particular full employment unemployment rate. More recent approaches have used a single production function, which at minimum includes a labor input variable and a capital input variable.

The accuracy of estimates of the output that could be expected at full employment has important implications for policymakers. For example, an overestimation of GNP at full employment would overstate the extent to which resources in the economy are currently underutilized. This may lead to policy actions that place too much demand pressure on existing capacity and worsen inflation. Conversely, underestimation of GNP at full employment may lead to policy actions that place too little demand on the economy's resources and hence slow its growth.

Some economists have questioned the meaning and usefulness of the concept of potential GNP because it explicitly ignores demand. Plosser and Schwert, for example, argue that potential GNP has little operational significance because:

> "It is not an equilibrium concept, since there is no relationship with aggregate demand. Consequently, 'potential GNP' cannot be viewed as representing the level of output which would prevail in the absence of any unexpected random shocks to aggregate supply or demand."[2]

[1] Peter K. Clark, "Potential GNP in the United States, 1948-80," *Review of Income and Wealth,* June 1979, pp. 141-65.

[2] Charles I. Plosser and G. William Schwert, "Potential GNP: Its Measurement and Significance, A Dissenting Opinion," *Carnegie-Rochester Conference Series on Public Policy,* Volume 10, supplementary series to the *Journal of Monetary Economics,* 1979, pp. 179-86.

John B. Penson, Jr., is a visiting scholar at the Federal Reserve Bank of Kansas City on leave from Texas A&M University. Kerry Webb is an assistant economist at the Federal Reserve Bank of Kansas City.

Gordon also faults estimates of potential GNP —a term he says has been discredited and is obsolete—because they do not explicitly relate to the behavior of wages and prices.[3] This raises a question as to whether policymakers can realistically expect to see the output levels suggested by estimates of potential GNP if they adopt policies to fully employ available resources, since these estimates explicitly ignore the economic factors influencing producers' and consumers' decisions.

This article presents a new approach to estimating GNP at full employment that explicitly accounts for both supply **and** demand. The first section presents a brief review of existing estimates of potential GNP and illustrates the need to account for the interrelationships between production sectors in the economy and their capacities when estimating GNP at full employment. The second section presents a nontechnical discussion of how supply and demand considerations were accounted for when estimating GNP at full employment in this study. A technical explanation of this approach is presented at the end of this article for the interested reader. Finally, this article presents annual estimates of GNP at full employment during the 1958-71 period and evaluates the national economic policy implications of differences between these estimates and estimates of potential GNP.

EXISTING MEASURES OF POTENTIAL GNP

Use of the gap between actual and potential GNP as a measure of the amount of slack in the economy first gained prominence in the early 1960s due to the efforts of the Council of Economic Advisers (CEA) and Arthur Okun. There are several features which distinguish the CEA's model based upon Okun's law, as it is often called, from the measurement procedures developed in recent years by Clark, Rasche and Tatom, and Perloff and Wachter.

Okun's Law

Okun proposed that potential GNP is the level of aggregate output associated with a full employment unemployment rate of 4 per cent.[4] Okun's law has been used in one way or another by the CEA since the early 1960s to measure potential GNP. In their approach, the CEA substitutes the full employment unemployment rate into an equation explaining the relationship between output and the rate of unemployment. This equation is then solved to determine the output level associated with the full employment unemployment rate. The effect of the full employment unemployment rate on potential GNP reflects not only the number of people working, but also the number of hours worked and productivity as well. Finally, the results are smoothed to remove sharp short-run fluctuations in this series.

The procedures used by the CEA assume that only the availability of labor and its productivity determine potential GNP. As Perry notes, however, "it is hard to argue that capital should not be included in estimating potential output because everyone **knows** it belongs in the calculation."[5] Okun, in fact, also recognized that capital should be incorporated into the measurement of potential GNP when he stated, "I shall feel much more satisfied with the

---

[3] R. J. Gordon, "A Comment on the Perloff and Wachter Paper," *Carnegie-Rochester Conference Session Public Policy,* Volume 10, pp. 187-94.

[4] Arthur M. Okun, "Potential GNP: Its Measurement and Significance," in American Statistical Association, *Proceedings of the Business and Economics Section,* 1962, pp. 98-104.

[5] George L. Perry, "Potential Output and Productivity," *Brookings Papers on Economic Activity,* The Brookings Institution, Washington, D.C., 1977, p. 11.

estimation of potential output when our data and our analysis have advanced to the point where . . . the capital factor can be explicitly taken into account."[6]

Other Measures

Several alternative procedures to measuring potential GNP which explicitly account for capital have been introduced since 1976. The first of these studies was completed by Clark while on the CEA staff.[7] The capacity shortages evidenced in 1973 and other factors had led the CEA to conclude that potential GNP should measure the output of the economy that could be produced under conditions not only of high labor utilization, but also of high capital utilization. Potential GNP as reported in the 1977 and 1978 *Economic Report of the President* represented the "output in 1972 dollars that the economy would produce if the Department of Commerce manufacturing capacity utilization rate were 86 per cent and the unemployment rate was 4.9 per cent."[8] Clark's explicit accounting of capital in measuring potential GNP was accomplished through the use of a single Cobb-Douglas production function for the whole economy, where the input shares for labor and capital were assumed to be two-thirds and one-third, respectively. As a result of Clark's study, significant reductions in the annual growth rate and level of potential GNP were reported in 1977.[9]

Rasche and Tatom also used an aggregate Cobb-Douglas production function to estimate potential GNP.[10] Their production function differed from Clark's because they (1) specifically included energy as a factor of production and (2) statistically estimated the input shares for the labor, capital, and energy inputs.[11] Perloff and Wachter used a translog production function to measure potential output to avoid the assumptions underlying the Cobb-Douglas production functions used in the Clark and Rasche-Tatom studies.[12]

Still another procedure for measuring potential GNP is the one presently practiced by the CEA. In the 1979 *Economic Report of the President,* the CEA expressed the feeling that productivity growth had not shown the significant improvement expected two years earlier. Hence, the CEA decided to revise downward its estimates of potential GNP during the 1970s. Further revisions were made in 1980 and 1981 in response to new information on productivity.[13] Two approaches were used in making these revisions. The first approach was based upon the use of Okun's law as described earlier. The

---

6 Okun, page 104.

7 Peter K. Clark, "Potential GNP in the United States, 1948-80," *U.S. Productive Capacity: Estimating the Utilization Gap,* St. Louis Center for the Study of American Business, Washington University, December 1979, p. 21.

8 *Economic Report of the President,* January 1977, p. 52.

9 Using Okun's procedure, the CEA had pegged the annual rate of growth in potential GNP at 4 per cent from the fourth quarter of 1968 to the fourth quarter of 1975, and 3.75 per cent thereafter. This led to a 1976 estimate of potential GNP of $1,422 billion, expressed in 1972 dollars. The Clark estimates, however, resulted in a 3.5 per cent growth rate from the fourth quarter of 1968 onward and an estimate of potential GNP in 1976 of $1,364 billion in 1972 dollars.

10 Robert H. Rasche and John A. Tatom, "Potential Output and Its Growth Rate—The Dominance of Higher Energy Costs in the 1970s," *U.S. Productive Capacity: Estimating the Utilization Gap,* pp. 67-120.

11 Thanh criticized both the Clark and Rasche-Tatom studies for their use of a Cobb-Douglass production function in a macro setting. See Pham Chi Thanh, "U.S. Productive Capacity: A Comment," both in *U.S. Productive Capacity: Estimating the Utilization Gap, pp. 157-65.*

12 *J. M. Perloff and M. L. Wachter, "A Production Function—Nonaccelerating Inflation Approach to Potential Output: Is Measured Potential Output Too High?" Carnegie-Rochester Conference Series on Public Policy,* Volume 10, p. 113.

13 See *Economic Report of the President,* January 1980 and 1981.

second procedure related cyclically adjusted labor productivity to potential output. Both estimates were then used as guides to establishing the published growth rates and levels of potential GNP.

Sector Capacities and Bottlenecks in GNP

All the procedures for estimating potential GNP, therefore, either explicitly ignore the role of the current capital stock in the economy or implicitly assume the input shares for capital and labor are the same in each production sector of the economy. The existing procedures also ignore the interrelationships among the production sectors and the possibility that one sector can limit the output of other sectors and hence the level of GNP. Klein and Long suggest that, "Capacity is a general equilibrium concept, which should be altered in light of bottlenecks whose effects can be traced through an input-output analysis."[14] This, they state, "is the whole point in using capacity utilization measures as signals of inflationary pressure, and accounts for (our) view that other measures strongly overstate the amount of spare capacity available by not taking account of interrelationships among industries." For example, an increase in the demand for automobiles will lead to an increase in the production of automobiles, which in turn requires more iron ore. The availability of labor for mining or the current capacity of the mining sector, however, may limit the amount of ore that can be produced in the short run.

If either the availability of labor or the current capacity of firms limits the output of just one production sector that supplies goods and services to other sectors, the economy's potential aggregate output will be limited. The mix of goods and services used in production by the individual production sectors will also change from one period to the next as the cost and availability of primary inputs and intermediate products change and as technology changes.

DESIRED GNP AT FULL EMPLOYMENT

Even if these factors are accounted for, one must still question whether producers in the economy at full employment would actually have desired to operate at the final demand levels suggested by existing estimates of potential GNP. As Greenspan suggests, the input-output analysis suggested by Klein and Long "requires not only some judgements about engineering relationships, but also a price vector that determines which materials or processes will be used."[15] In measuring GNP at full employment, it is not enough to account only for the physical production process. One must also account for the changes in the relative prices of products and resources as the economy moves from current GNP to full employment GNP, and for the effects these price changes will have upon the economic decisions of producers and consumers.

Measurement of Desired GNP at Full Employment

This study uses a series of annual input-output models of the U.S. economy to estimate GNP at the general equilibrium associated with the full employment of available labor (or capital, should it become limiting before labor is fully employed). The economy is in general equilibrium when a set of prices exist at which

---

[14] Lawrence R. Klein and Virginia Long, "Capacity Utilization: Concept, Measurement and Recent Estimates," *Brookings Papers on Economic Activity,* The Brookings Institution, Washington, D.C., 1973, pp. 45-56.

[15] Alan Greenspan, "Comments and Discussions," *Brookings Papers on Economic Activity,* The Brookings Institution, Washington, D.C., 1973, pp. 757-9.

the quantities of goods and services demanded by consumers are satisfied by the quantities supplied by producers who have used resources supplied at the going prices and wages. To distinguish between these estimates of GNP at full employment and the estimates of potential GNP, these estimates are referred to as "desired" GNP at full employment, reflecting the fact that, at this particular level of GNP, producer profits are maximized and consumer demands are satisfied.

Data used to develop the annual models used in this study were obtained from the 85-sector input-output transaction tables published by the U.S. Department of Commerce. There are eight production sectors in these annual models: agriculture, mining and quarrying, construction, manufacturing, processed food and tobacco, energy, services, and trade and transportation. A technical description of the model is presented in the Appendix.

To find desired GNP at full employment for selected years during the 1958-71 period, the annual models first had to be constrained by the capacity of selected production sectors and the availability of labor.[16] The next step was to assure that the demand for labor completely exhausted the full employment labor force. The objective of each annual model thus was to find that particular final demand for goods and services where: (1) the demand for labor fully exhausts the full employment labor force, or the output of selected production sectors is limited by their capacities, and (2) the economy is in general equilibrium—that is, producer profits are maximized and consumer demand is satisfied at the going wages and prices. Any other level of GNP at full employment would necessarily imply that the quantity that producers were willing to supply at the going wages and prices differed from the quantity demanded by consumers.

Differences From Other Approaches

This approach to measuring GNP at full employment differs from the approaches used to estimate potential GNP in three major ways.

First, since input-output analysis traces the direct and indirect effects of changes in the demand and supply of products and resources in the economy, the interrelationships among the production sectors can be taken into account. This means that, rather than using one equation to represent all production activity, each key production sector in the economy has a separate production function. By limiting the output of selected sectors to their current capacity, this disaggregated approach can identify the effects that sector capacity can have upon the level of GNP.[17] During the time period covered by this study, however, the capacity of the individual production sectors never placed a limit on the size of GNP before the full employment labor force was completely put to work. Instead, the size of the full employment labor force suggested by Clark's annual full employment unemployment rates was the limiting factor. This result does not diminish either the need to account for the effects that sector capacity can have upon the level of GNP, or the uniqueness of the model used in this study. As indicated earlier, capacity shortages have been evidenced since the time period covered by this study. In addition, the

[16] This time period was determined by the availability of input-output tables when this model was developed.

[17] To measure the current manufacturing capacity of the manufacturing, food processing and tobacco, mining and quarrying, and energy sectors, their total output was divided by specific capacity utilization indices published by the Federal Reserve Board. It was assumed that the output of the construction, services, and transportation and trade sectors would not be capacity limiting. Finally, the capacity of the agriculture sector was found using the "trends-through-peaks" method described by Klein and Long.

approach taken to measure GNP at full employment in this study differs from previous approaches in two other ways.

The second major departure is that the model developed in this study accounts for annual changes in the input shares for labor, capital, and other inputs resulting from technological advances as well as changes in relative prices. By using annual systems of sector level production functions instead of a single production function for the entire economy, this study accounts for the year-to-year substitution among inputs in each production sector.

The third major departure from previous approaches is that this study explicitly accounts for demand as well as supply. Relative prices play a role in determining not only the intermediate demand for specific goods and services at full employment, but final demand as well. Intermediate demand by a production sector for the output of other sectors will change as the demand for its own goods and services changes. The final demand for a particular sector's product by other producers as well as by consumers will be influenced by the product's price and the price of substitute products. The estimates of desired GNP at full employment developed in this study, therefore, reflect the general equilibrium combination of goods and services associated with the going prices and wages and the full employment of labor.[18]

[18] Remember that there was the possibility that the capacities of one or more key production sectors would have been reached before the full employment labor force was employed. As indicated earlier, however, this did not occur during the time period covered by this study. The difference between the concept of potential GNP and the concept of desired GNP at full employment developed in this study is similar to the difference between the concepts of engineering capacity and economic capacity at the firm or sector level. See Lawrence R. Klein, "Some Theoretical Issues in the Measurement of Capacity," *Econometrica,* 1960, pp. 272-86.

COMPARISON OF ALTERNATIVE ESTIMATES

Estimates of desired GNP at full employment given by the annual models in this study are presented in Table 1, along with actual GNP and the estimates of potential GNP given by the CEA's model based upon Okun's law, the Clark model, and the Rasche-Tatom model. The annual growth rates for each GNP measure are presented here as well.

Both the Clark and Rasche-Tatom models, which explicitly account for the role of capital, result in substantially lower estimates of potential GNP than the published CEA estimates based on Okun's law. The annual estimates of desired GNP at full employment developed in this study deviate substantially from all the potential GNP estimates, however. There are two major reasons for the deviation. First, models not explicitly accounting for the interrelationships among the production sectors will overstate the total amount of spare capacity in the economy. As indicated in the previous section, the annual models used in this study to estimate desired GNP at full employment take these interrelationships into account. Second, these estimates also reflect the general equilibrium GNP associated with the full employment of available labor. While labor could possibly have been allocated differently among the sectors to increase GNP, this would have meant lower profits for producers in light of the going wages and prices.

A comparison of the annual growth rates suggested by the various estimates of potential GNP and the estimates of desired GNP at full employment made in this study helps illustrate the inherent differences between these approaches. All the approaches which explicitly account for capital show *declining* annual rates of growth in GNP at full employment during 1968-69 and 1969-70, while the CEA's estimates based upon Okun's law suggest *increasing*

annual rates of growth. The annual rates of growth in desired GNP at full employment estimated in this study also exhibit greater volatility than the estimates of potential GNP. In 1969, when interest rates rose substantially and corporate profits declined somewhat, the rate of growth in desired GNP at full employment fell from 4.3 to 2.4 per cent. Only the Clark model indicated a slower rate of growth in potential GNP from the year before. And in 1970, when interest rates rose still further and corporate profits declined sharply, the rate of growth in desired GNP at full employment suggests that consumers and producers would have desired only 1 per cent more in GNP at full employment than they desired in the previous year. Thus, the annual rates of growth in desired GNP at full

Table 1
ESTIMATES OF GNP AT FULL EMPLOYMENT, LEVEL, AND RATE OF GROWTH
Selected Years, 1958-71

Year	(1) Actual GNP	(2) Potential GNP: CEA (Okun's law)	(3) Potential GNP: Clark Model	(4) Potential GNP: Rasche-Tatom Model	(5) Desired GNP at full Employment
Level of GNP	-Billions of 1972 Dollars-				
1958	679.5	728.0	721.5	723.1	694.6
1961	755.3	807.1	801.1	793.5	773.4
1963	830.7	865.9	858.6	842.8	841.9
1966	981.0	967.0	957.8	953.0	973.2
1967	1,007.7	1,003.0	994.8	990.8	999.7
1968	1,051.8	1,040.9	1,031.8	1,030.0	1,043.0
1969	1,078.8	1,081.6	1,069.2	1,076.4	1,067.6
1970	1,075.3	1,124.9	1,106.0	1,114.9	1,077.8
1971	1,107.5	1,169.9	1,145.4	1,152.8	1,120.4
Growth Rate in GNP	-Per Cent-				
1958-61*	3.7	3.6	3.7	3.3	3.8
1961-63*	5.0	3.6	3.7	3.3	4.4
1963-66*	6.0	3.9	3.9	4.4	5.2
1966-67	2.7	3.8	3.9	4.0	2.7
1967-68	4.4	3.8	3.9	4.0	4.3
1968-69	2.6	3.9	3.6	4.5	2.4
1969-70	−0.3	4.0	3.4	3.4	1.0
1970-71	3.0	4.0	3.6	3.0	4.0

*Annual average growth rate during the period.

employment reflect the growth rates in *actual* GNP observed during the 1958-71 period more closely than they do the growth rates in the estimates of potential GNP. This is because the approach to measuring desired GNP at full employment incorporates not only the longer-run decisions of producers to expand their existing capital stock as the Clark and Rasche-Tatom models do, but also the short-run decisions of producers to utilize that portion of their existing capital stock which maximizes their profits.

Inflation and GNP at Full Employment

Economists recognize that inflation doesn't wait for full employment. That is, prices in general begin to rise before full employment is reached, as growth in economic activity puts increasing demand pressure on the capacity of key production sectors in the economy. Which measure of GNP at full employment—potential GNP or desired GNP at full employment—most closely reflects the inflationary pressures which existed during the 1958-71 period?

One way to address this question is to compute the gaps between actual GNP and the GNP levels at full employment suggested by the various estimates and then relate these annual gaps to the annual rates of inflation observed during the 1958-71 period. The gaps suggested by the CEA's estimates based upon Okun's law, the Clark model, the Rasche-Tatom model, and the annual models developed in this study are presented in Table 2.

There is a substantial difference between the size of the gaps suggested by these estimates of full employment output. In 1970, for example, the CEA's published estimate of the gap was +$49.6 billion—that is, actual GNP was nearly $50 billion less than estimated potential GNP. Thus, producers may have been expected to supply an additional $50 billion to final

Table 2
GAPS BETWEEN ACTUAL GNP AND VARIOUS MEASURES OF GNP AT FULL EMPLOYMENT, AND THE RATE OF INFLATION,
Selected Years, 1958-71†

	(1)	(2)	(3)	(4)	(5)
	----------Potential GNP----------				
Year	CEA (Okun's law)	Clark Model	Rasche-Tatom Model	Desired GNP at full employment	Rate of Inflation
	-Billions of 1972 Dollars-				-Per Cent-
1958	+48.5	+42.0	+43.6	+15.1	1.8
1961	+51.8	+45.9	+38.2	+18.1	1.5
1963	+35.2	+27.9	+12.1	+11.2	1.6
1966	−14.0	−23.2	−28.0	− 7.8	3.4
1967	− 4.7	−12.9	−16.9	− 8.0	3.0
1968	−10.9	−20.0	−21.8	− 8.8	4.7
1969	+ 2.8	− 9.6	− 2.4	−11.2	6.1
1970	+49.6	+30.7	+39.6	+ 2.5	5.5
1971	+62.4	+37.9	+45.3	+12.9	3.4

† A positive gap means that actual GNP is less than GNP at full employment.
A negative gap means that actual GNP is greater than GNP at full employment.

Table 3
STATISTICAL ANALYSIS OF RELATIONSHIP BETWEEN INFLATION AND PER CENT GAP BETWEEN ACTUAL GNP AND GNP AT FULL EMPLOYMENT[a]

Model	B_0	B_1	DW	Rho	F	$\bar{R}^2$
Penson-Webb model	1.2619 (4.796)	−38.3757 (− 2.815)	2.04	.52	7.92	.46
Clark model	1.3011 (3.646)	−12.8437 (− 2.013)	1.92	.60	4.05	.28
CEA (Okun's law) model	1.4183 (3.181)	−11.5605 (− 1.757)	1.87	.65	3.09	.21
Rasche-Tatom model	1.2422 (2.827)	− 9.9856 (− 1.389)	1.76	.65	1.93	.10

[a] The estimating equation used in this analysis is of the form $\log p = B_0 + B_1 (PGAP)$, where log p represents the per cent change in the Consumer Price Index and PGAP represents the per cent gap between potential and actual GNP associated with the various models. The values reported in the parentheses below the B_0 and B_1 coefficients represent the ratio of the coefficient to its standard error. DW represents the Durbin-Watson test statistic, Rho is the coefficient associated with the first order autocorrelation correction scheme, F represents the F ratio, and $\bar{R}^2$ represents the corrected coefficient of multiple correlation.

demand if full employment of labor was achieved. The gap suggested by the estimate of desired GNP at full employment of +$2.5 billion, however, suggests that producers would not have appreciably expanded their output in 1970 even if labor were fully employed.[19] And in 1969, all the estimates of potential GNP suggested either a declining inflationary gap (less negative than the previous year) or a deflationary gap (actual GNP below GNP at full employment) even though the rate of inflation jumped from 4.7 to 6.1 per cent. Only the estimate of desired GNP at full employment developed in this study suggests an increasing inflationary gap, which is consistent with an increasing rate of inflation.

The statistical relationship between the annual rate of inflation and the percentage gap between actual GNP and the various measures of GNP at full employment is examined in Table 3.[20] Of those models estimating potential output, the Clark model did a better job of highlighting the inflationary pressures which existed during 1958-71 than either the CEA's model based upon Okun's law or the Rasche-Tatom model. The results presented in Table 3, however, show that the concept of desired GNP at full employment explained more of the

[19] The additional labor utilized was allocated among the sectors so as to maximize the gain (or minimize the loss) in the economic well-being of producers and consumers in general.

[20] This is not to suggest that the gap between potential or desired GNP and actual GNP is the only cause of inflation. Our interest is in the partial relationship between these two variables. For an extended analysis of inflation, which includes other variables like the expected inflation rate, see Robert J. Gordon, "A Consistent Characterization of a Near-Century of Price Behavior," *American Economic Review*, May 1980, pp. 243-8, and Jon Frye and Robert J. Gordon, "Government Intervention in the Inflation Process: The Econometrics of Self-Inflicted Wounds," *American Economic Review*, May 1981, pp. 288-94.

inflationary pressures which existed during the 1958-71 period than the concept of potential GNP. This equation not only had the highest corrected R-square, but also was the only equation which had a statistically significant F-ratio at the 5 per cent level of significance.

POLICY IMPLICATIONS

The estimates of desired GNP at full employment presented in this study suggest several factors of interest for economic policy. First, estimates of potential GNP at full employment based largely on an aggregate relationship between output and one or more inputs will overstate the economy's output at full employment, particularly in periods of weak economic conditions. Producers simply may not desire to supply the output at full employment suggested by estimates of potential GNP because the cost of producing additional output exceeds the additional returns they would receive.

In 1970, for example, the CEA estimate of potential GNP suggests a gap between actual and potential GNP of about $50 billion. With a GNP gap of that size, economic policy could afford to be expansionary in order to put unused resources to work without much of an increase in inflation. But if the gap were only $2.5 billion, as suggested by the estimate of desired GNP at full employment, the same amount of policy stimulus would exert too much demand pressure on the economy's capacity to produce, and thus subtantially increase inflation.

The estimates of potential GNP suggest specific levels of output that would be forthcoming if resources were fully employed. Thus fiscal policymakers, in taking action to move the economy to full employment, would expect a particular level of tax revenue at full employment. If producers desired to supply less output at full employment than the estimated level of potential GNP, however, tax revenues would fall short of expectations, as would the actual budget surplus. If a budget deficit existed, there would be further inflationary implications.

Finally, policymakers would be in a better position to aim specific programs toward those sectors which represent bottlenecks to GNP if they were provided with estimates of GNP at full employment on a disaggregated basis. By using an approach to measuring GNP at full employment which captures the interdependencies that exist among production sectors, a sector which limits the output of other sectors can be discovered more easily. Furthermore, an examination of the added economic benefits to producers and consumers from the expansion of specific sectors in the economy can help policymakers design specific programs to expand the economy that will most benefit producers and consumers in general. Such an analysis is impossible with existing models, not only because of their aggregate nature, but also because they explicitly ignore demand.[21]

SUMMARY

Estimates of GNP at full employment can be valuable in estimating the output lost due to idle resources in the economy, and in shaping short term policies that will eliminate this gap. Although several methods have been used to estimate potential GNP, these methods ignore the interrelationships between the production sectors in the economy and the demand for

---

21 One obvious disadvantage to the approach taken in this study to measure GNP at full employment is the dated nature of available input-output tables. While this issue was not pursued in this article, several techniques are available for projecting the technical coefficients beyond those presently available which insure a consistency with up-to-date totals for total output and labor use. Future research plans include development of annual input-output models to estimate desired GNP at full employment during the 1972-80 period, and the development of an input-output model capable of projecting future desired GNP under specific policy assumptions.

goods and services.

An approach to measuring the final demand levels desired by producers and consumers at full employment that accounts for these sector interrelationships was presented in this article. The annual estimates of GNP at full employment reported for the 1958-71 period showed more year-to-year volatility than existing estimates of potential GNP because the measurement approach taken accounts for (1) the interrelationships among the production sectors and (2) the demand for goods and services, as well as producers' desires to utilize their existing capital stock at going wages and prices, if labor is fully employed. The resulting estimates of desired GNP at full employment were shown to more fully explain the inflationary pressures which existed during the 1958-71 period. Future research designed to extend this analysis to the present is under way.

TECHNICAL APPENDIX

The approach taken to estimate desired GNP at full employment involved the development and use of a set of annual quadratic input-output models. A quadratic input-output model, by incorporating econometric estimates of the final demand and primary input supply functions into an input-output model's general equilibrium framework, overcomes a major objection to the Leontief model: perfectly elastic product supply curves and an exogenously determined final demand. The model used in this study is formulated as follows:

(1) Maximize $Z = C'Q + 1/2\, Q'DQ$

subject to:

(2) $SQ \leq 0$

(3) $Q \geq 0$

(4) $X \leq M_X$

(5) $R_\lambda \leq M_\lambda$

where

Z = value of the objective function,

Q = (m + 2n)-element column vector of quantities,

C = (m + 2n)-element column vector of price intercepts for the inverse primary input supply and final demand functions,

D = (m + 2n) × (m + 2n) negative definite or negative semi-definite matrix of slope coefficients in the inverse primary input supply and final demand functions (including cross price effects),

S = (m + n) × (m + 2n) matrix of production function coefficients,

O = (m + 2n)-element column vector of zeros,

X = n-element column vector of total output,

M_X = n-element column vector of sector manufacturing capacities,

R_λ = demand for labor services in the economy, and

M_λ = total available labor services.

Equation 2 represents the fixed proportion production functions in the Leontief formulation, while equation 3 requires a non-negative solution for each sector's output. Finally, equation 4 limits the output of each production sector to its manufacturing capacity, while equation 5 limits total employment in the economy to the "full employment" labor force. Solving equation 1 subject to equations 2 through 5 is equivalent to maximizing total producer and consumer surplus provided the integrability conditions hold and the D matrix is negative definite or negative semi-definite.

Sectoring the Model

The eight-sector model of the U.S. economy developed in this study represents an aggregated version of the 85-sector input-output table published by the U.S. Department of Commerce. The eight production sectors include: (1) agriculture, (2) mining and quarrying, (3) construction, (4) manufacturing, (5) processed food and tobacco, (6) energy, (7) services, and (8) trade and transportation. This aggregated eight-sector table was then used to calculate the technical coefficients in the S matrix in equation 2.

Estimating the D Matrix

The next step in developing a quadratic input-output model is to estimate the slope coefficients for the final demand and primary input supply functions appearing in the D matrix in equation 1. Final demand in an aggregated input-output table includes gross private capital formation, changes in business inventories, government demand (all levels), and net export demand in addition to the traditional consumer demand by the household sector. Given the dominant nature of personal consumption expenditures in total final demand, however, consumer theory should play a large part in conceptualizing the estimating equations. Data aggregated across production sectors also cause difficulties when conceptualizing the final demand for the aggregated sector's product. Having acknowledged these difficulties, the final demand equations for the products emanating from the first seven sectors take the general form:

$$(6)\quad Y_i = b_{i0} + \sum_{j=1}^{n} b_{ij} P_j + \sum_{j=n+1}^{m} b_{ij} Z_{ij} \qquad (i = 1, 2, \ldots, 7)$$

where Y_i is the quantity of final demand for goods and services from the ith sector, P_j is the real price of the good or service produced by the jth sector, and Z_{ij} is the jth exogenous variable hypothesized to affect the final demand for the ith sector's product. The exogenous variables include expected personal disposable income as well as those variables like the exchange rate thought to influence non-household final demand.

The final demand equation for the trade and transportation sector is specified to be a linear function of the final demand for each of the other sector's products except construction and services, which have zero margins. This equation for the jth year takes the form:

$$(7)\quad Y_{8j} = \sum_{i=1}^{6} \xi_{ij} Y_{ij} \qquad (i = 1, 2, 4, 5, 6)$$

in which the ξ_{ij} weight representing the ith sector in the jth year is given by

$$(8)\quad \xi_{ij} = (T_{i,72}/Y_{i,72}) \times (Y_{8,72}/Y_{8,j})$$

where $T_{i,72}$ represents the transportation and trade margin for the products emanating from the ith sector in 1972, $Y_{i,72}$ is the final demand for the ith sector's products (excluding imports) in 1972, $Y_{8,72}$ is the final demand for transportation and trade services in 1972, and $Y_{8,j}$ represents the final demand for transportation and trade services in the jth year if the first term in equation 8 was left unadjusted.

Data on final demand used in estimating equation 10 was obtained from the 85-sector input-output tables published by the U.S. Department of Commerce for 1958, 1961, 1963, 1966, 1967, 1968, 1969, 1970 and 1971. These values were first aggregated up to the eight sectors adopted in this study and then deflated by an appropriate price deflator to arrive at a measure of quantity. Sector 1 (agriculture) includes sectors 1-4 in the 85-sector model; sector 2 (mining and quarrying) includes sectors 5-10; sector 3 (construction) includes sectors 11 and 12; sector 4 (manufacturing) includes sectors 13, 16-30, 32-64, 82, and 83; sector 5 (food processing and tobacco) includes sectors 14 and 15; sector 6 (energy) includes sectors 31 and 68; sector 7 (services) includes sectors 66, 67, 70-79, 81, and 84-87; and sector 8 (transportation and trade) includes sectors 65 and 69. The individual price indices for the products sold by each sector and the GNP price deflator used to express prices in real terms were also obtained from U.S. Department of Commerce publications.

Data and statistical problems necessitated some changes to the final specifications for the estimating equations. Because of the limited number of observations available to estimate the coefficients in equation 6 for each sector and the potential problems caused by multicollinearity among the price variables, the total number of independent variables used in each equation was restricted. Missing years within the data series also precluded the use of lagged endogenous variables in the model.

All equations achieved an F-ratio statistically significant from zero, and all equations have coefficients with the signs suggested by theoretical considerations. Since the coefficients on the exogenous variables in these equations (Z_{ij}) are folded into the intercept term in the objective function of the model, our interest here is in the coefficient estimates associated with P_i. All but three of these coefficients estimates are greater than their corresponding standard errors. Furthermore, all the own price coefficients along the diagonal in this table have the expected negative sign. The signs for the coefficients off the diagonal of course can be either positive or negative (i.e., complements or substitutes). The model developed in this study also contains three primary input supply functions: labor, noncomparable imports, and all other primary inputs.

Estimating the C Vector

Given the slopes of the inverse final demand and primary input supply functions and the observed price-quantity coordinates for these products and inputs, the next step is to substitute this information into the D matrix in equation 1 and then calculate the intercepts for each function. The intercepts in the C vector in equation 1 are given by the point of intersection between the price axis and linear segments with the slopes recorded in the D matrix passing through the equilibrium price-quantity coordinates.

A more detailed explanation of this model is provided by John B. Penson, Jr., Hovav Talpaz, and Henry S. Foster, "Estimation and Validation of Quadratic Input-Output Models," Research Working Paper 81-2, Research Department, Federal Reserve Bank of Kansas City, 1981.