CBO MEMORANDUM

CBO'S METHOD FOR ESTIMATING
POTENTIAL OUTPUT

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The Congressional Budget Office's (CBO's) estimate of potential output plays an important role in its economic forecast. This memorandum describes how CBO estimates and projects potential output. It also compares the estimates of other agencies and discusses the advantages and disadvantages of alternative methods.

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SUMMARY

Evaluating the state of the economy, gauging inflationary pressures, and projecting long-term growth require a measure of the economy's productive capacity. One such measure, referred to as potential output, is an estimate of the level of output consistent with a stable rate of inflation. Output can exceed its potential level, but only at the risk of increasing inflation. Similarly, when an economic slowdown drives output below its potential level, inflation generally recedes.

Potential output is an important component in the Congressional Budget Office's (CBO's) economic forecast. It plays a role in the long-term projection for real gross domestic product (GDP) in the forecast for inflation, and it is used to compute the standardized-employment deficit, which is an important indicator of the direction of fiscal policy.

Estimating Potential Output

CBO uses the framework of a neoclassical growth model to estimate historical values and project future values of potential output. Growth models use a neoclassical production function, combined with assumptions about the growth of the labor force and the rate of saving, to determine how output will grow over the long term. The primary advantage of using a growth model to estimate and project potential output is that it explicitly recognizes the contribution of capital to production, unlike some methods of estimating potential output.

CBO bases its measure of potential output on real GDP, which comprises five sectors: nonfarm business, farm, government, nonfarm housing, and households and nonprofit institutions. Since different sectors use different methods of production, using a single production function to model overall output would be inappropriate. Also, the necessary data are unavailable for some of the sectors, which prevents the use of a single production function for the whole economy. For these reasons, CBO splits real GDP into its components before adjusting each to its potential level.

The most important sector in the model is the nonfarm business sector. It is the largest sector in the economy and the one for which the neoclassical production function is specified. The production function has three inputs: hours worked, the capital stock, and total factor productivity. To estimate potential output in the nonfarm business sector, the labor input (hours worked) and total factor productivity are adjusted to their potential levels and then substituted back into the production function. Adjusting the capital stock in a similar fashion is not

necessary because the potential capital stock will be highly correlated with the actual stock of capital.

The potential levels of the labor and productivity inputs are calculated with a cyclic-adjustment equation. That equation, which removes the effects of the business cycle, includes the variable to be adjusted as the dependent variable, with the unemployment gap and several time trends as explanatory variables. The unemployment gap is the difference, in percentage points, between the unemployment rate and the nonaccelerating inflation rate of unemployment (NAIRU). The NAIRU provides a benchmark that determines when the economy is at a high rate of resource use. Once the equation has been estimated statistically, it will provide an estimate of what the dependent variable would have been over time had the unemployment rate been equal to the NAIRU in every year of that period; that is, it computes the potential level of that variable.

The capital input to production is based on the values of the net stock of private capital in the nonfarm business sector, in constant dollars. However, simply using the total capital stock would paint a misleading picture of overall capital accumulation because doing so would ignore the fact that various types of capital differ in their durability and productivity. Therefore, the capital input in the growth model is an index designed to measure the flow of capital services available for production. That index accounts for the fact that different types of capital have different levels of productivity.

Potential output in each of the sectors other than nonfarm business is computed directly, using CBO's cyclic-adjustment equation. This procedure differs slightly from that used for the nonfarm business sector, where the inputs are adjusted to their potential levels and then substituted into the production function. Output in each of the other sectors is adjusted independently, using the same procedure. The sole exception is the housing sector. Since output in that sector is not greatly influenced by the business cycle, potential output in that sector is assumed to equal actual output.

Projecting Potential Output

Projecting potential output using the growth model is straightforward: once the model's exogenous (or independent) variables have been projected, the model can be solved to compute potential output. The key exogenous variables are the growth of the labor force, the rate of national saving, and the growth of total factor productivity. With projections of those and other, subsidiary variables, the model projects the rate of capital accumulation and, using the production function, potential output.

CBO's Estimate of Potential Output

CBO's estimate of potential output provides a useful measure of the capacity of the U.S. economy. Real GDP typically falls below potential GDP during recessions whereas expansions often drive the level of real GDP above potential. The GDP gap--the difference between output and potential output--does a good job of predicting the direction of changes in inflation. When output is below its potential level, then the rate of inflation generally falls; when output is above the level of potential, then inflation generally climbs.

Advantages and Disadvantages of the Growth Model

The primary advantage of using the framework of a growth model to estimate and project potential output is that it explicitly includes capital as a factor of production. Including capital has theoretical appeal; economic theory suggests that the ability of a firm or economy to produce will be influenced by the size of its capital stock, so any measure of potential output should reflect the size of that stock. Including capital also makes CBO's projections for potential output fully consistent with its projection for the federal deficit, allowing CBO to incorporate the effects of changes in fiscal policy into its medium-term (seven-year) projection. Those changes affect the rate of national saving, which in turn influences the rate of capital accumulation and the growth of potential output.

CBO's growth model is also highly disaggregated and thus reveals more insights about the economy than would a more aggregated model. Data on the capital stock indicate that U.S. manufacturers have shifted their investment during the past few decades toward equipment (and away from structures) and have dedicated a greater proportion of their investment in equipment to computers. Both of those shifts have directed investment toward more productive types of capital, an effect that would not be captured by a model that included only the total capital stock.

The primary disadvantage of using a model based on a production function to estimate potential output is that including the capital stock may introduce measurement error. That problem afflicts many economic variables, but it is particularly acute for capital. Errors may arise when economic depreciation--the decline in efficiency resulting from wear and tear or scrappage--is measured and when many types of capital goods (that differ in terms of productivity) are aggregated into a single index of capital input.

Another limitation of the model is that its projections are quite sensitive to the assumptions made about total factor productivity and the rate of national saving. Even small changes to the projections of those variables, resulting perhaps from new information or revised data, can have large effects when compounded over a 10-year projection horizon. Also, the model is a fairly simple representation of the economy and therefore does not include all possible channels of the influence of fiscal policy on long-run growth. For example, there is no explicit link between tax rates and such variables as labor supply, productivity, or saving rates. However, the model does not preclude such effects; if a policy change is large enough to have an effect on those variables, then the impact could be included in the projections very easily.

INTRODUCTION

Assessing current economic conditions and projecting such variables as growth and inflation require a summary measure of the productive capacity of the economy. That measure, known as potential output, is an estimate of the level of output attainable when the economy is operating at a high rate of resource use. It is not, however, a ceiling on output that cannot be exceeded. Rather, it is the level consistent with a stable rate of inflation: if output rises above potential, then constraints on capacity begin to bind and inflationary pressures build; if output falls below potential, then resources are lying idle and inflationary pressures abate.

Such fluctuations of output around potential are a regular feature of the business cycle--recessions typically drive output below potential, and expansions frequently push output above it. Comparing the growth rates of actual and potential output allows analysts to determine whether the gross domestic product (GDP) gap--the percentage difference between actual and potential output--is shrinking or growing.

Potential output plays a role in several areas associated with the Congressional Budget Office's (CBO's) economic forecast. In particular, CBO uses potential output to set the level of real gross domestic product in its medium-term (seven-year) projections; it does so by closing the GDP gap that remains at the end of the short-term forecast. CBO also uses the level of potential output to gauge inflationary pressures. For example, an increase in inflation that occurs when real GDP is below potential (and monetary growth is moderate) can probably be attributed to temporary factors and is unlikely to persist. In addition, potential output is an important input in computing the standardized-employment deficit, which CBO uses to evaluate the stance of fiscal policy and reports regularly as part of its mandate.

POTENTIAL OUTPUT BASED ON A GROWTH MODEL

CBO calculates historical values and projects future values of potential output using the framework of a standard neoclassical growth model.[1] Growth models employ a neoclassical production function and assumptions the analyst makes about growth in the labor force and the rate of national saving to determine how output will grow over the long term.[2]

1. CBO's model is based on one originally developed by researchers at the Brookings Institution to analyze the Social Security trust fund. See Henry J. Aaron, Barry P. Bosworth, and Gary T. Burtless, *Can America Afford to Grow Old?* (Washington, D.C.: Brookings Institution, 1989) for a description of the original model.

2. CBO's method for estimating potential output is similar to the methods used by the International Monetary Fund and the Organization for Economic Cooperation and Development. See Charles Adams and David Coe, "A Systems Approach to Estimating the Natural Rate of Unemployment and Potential Output for the United States,"

The crucial advantage of using a growth model to calculate potential output is that its framework includes the capital stock--a fundamental input to production. Not all methods do; some include only the labor input, and others rely solely on the historical behavior of real GDP to estimate potential output. Perhaps more important, CBO's framework models explicitly the factors that determine the accumulation of capital, so the projection for the capital stock is fully consistent with CBO's projections for private saving and federal deficits. Specifically, a higher projected rate of saving will lead to faster accumulation of capital and faster growth of potential output. Therefore, lower government deficits, which raise the rate of national saving, will speed the growth of the capital stock and potential output in the model. Conversely, a recession that depresses the private saving rate will also temporarily slow the accumulation of capital and the growth in potential output.

CBO measures potential output as real gross domestic product adjusted to its potential level.[3] GDP comprises the output of five sectors: nonfarm business, government, farm, households and nonprofit institutions, and residential housing, as shown in equation (1). The nonfarm business sector is by far the largest of the five. In 1994, for example, output in that sector composed 77 percent of real GDP, compared with less than 10 percent for each of the other sectors. The model must also include a statistical discrepancy that measures the difference between total income and total output, because output is disaggregated by sector on the income, not the product, side of the national income and product accounts (NIPAs). The statistical discrepancy would always equal zero if it were possible to measure the components of output and income without error. In addition, GDP plus gross foreign product (the return to domestic residents on factors of production held abroad minus the return to foreigners on factors of production held in the United States) equals gross national product, as in equation (2).

(1) $$GDP = GDP_{nfb} + GDP_{govt} + GDP_{farm} + GDP_{hhnp} + GDP_{housing} + \text{statistical discrepancy}$$

(2) $$GNP = GDP + \text{gross foreign product}$$

where GDP = gross domestic product,
GDP_{nfb} = gross domestic product in the nonfarm business sector,
GDP_{govt} = gross domestic product in the government sector,

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IMF Staff Papers, vol. 37 (June 1990), pp. 232-293; and Raymond Torres and John P. Martin, "Potential Output in the Seven Major OECD Countries," *OECD Economic Studies*, no. 14 (Spring 1990), pp. 127-149.

3. CBO currently bases its estimate of potential output on the fixed-weighted, or 1987-dollar, measure of real GDP in the national income and product accounts. The Bureau of Economic Analysis has announced that it will feature a new measure of real GDP--the chain-type annual-weighted index--when it revises the NIPAs in December 1995. CBO will update its estimate of potential output, basing it on the new measure of real GDP, once the new data have been released.

GDP_{farm} = gross domestic product in the farm sector,
GDP_{hhnp} = gross domestic product in the households and nonprofit institutions sector,
$GDP_{housing}$ = gross domestic product in the housing sector, and
GNP = gross national product.

CBO uses this disaggregated approach to compute potential output for two basic reasons. First, different sectors have different methods of production; some rely more heavily on their capital stock, others more on their workforce. Using a single production function to model GDP, which amounts to specifying a production method, would therefore be inappropriate. Second, data limitations prevent the estimation of a single production function for GDP. A complete set of data on factor inputs (that is, capital and labor) is available for the nonfarm business sector, but data for many of the other sectors are incomplete. The missing data affect the way some of the sectors are modeled.

Equations (1) and (2) form the basis for estimating potential GDP and potential GNP. The model computes potential output in each sector and then computes potential GDP and GNP as the sum of the individual sectors.

$$GDP^* = GDP^*_{nfb} + GDP^*_{govt} + GDP^*_{farm} + GDP^*_{hhnp} + GDP_{housing} + \text{statistical discrepancy}^* \quad (1')$$

$$GNP^* = GDP^* + \text{gross foreign product} \quad (2')$$

where (*) denotes the potential values for a series.[4] Gross foreign product is not adjusted to potential because it is weakly related to the U.S. business cycle.

Output in the residential housing sector does not need to be adjusted to potential because it is largely unaffected by the U.S. business cycle. The Department of Commerce measures that output--the flow of housing services--as the sum of all rents paid to the owners of the housing stock, including rent paid to others as well as an imputed rent on owner-occupied housing.[5] Although investment in residential housing displays a marked cyclical pattern, the services that flow from the existing stock do not. Therefore, potential output in the housing sector is assumed to equal

4. The statistical discrepancy, though marked with an asterisk in equation (1′), is not adjusted to potential. However, some of the year-to-year variation in the series is removed using a three-year, centered, moving average. That variation, which arises entirely because of measurement error, is removed to prevent it from affecting the estimate of potential output.

5. The sum is adjusted to avoid double-counting payments for intermediate goods and services, such as property insurance, maintenance, and durable goods (appliances). Those adjustments are a small proportion of the total.

actual output in all time periods, and actual values of housing output are used to compute potential GDP.

Gross foreign product also lacks a strong cyclical component and therefore does not need to be adjusted. In the NIPAs, this variable is measured by U.S. receipts of factor income from foreigners minus U.S. payments of factor income to foreigners. Although factor income includes employee compensation, the bulk of it comes from undistributed corporate profits, interest, and dividend payments--income flows that are only loosely related to the U.S. business cycle. Historical values of potential GNP are computed as the sum of potential GDP and historical values of gross foreign product.

ESTIMATING HISTORICAL VALUES OF POTENTIAL OUTPUT

Estimates of the historical values of potential output are heavily dependent on the estimate of potential output in the nonfarm business sector. For that sector, CBO uses the growth model's production function, which explains the growth of output in terms of three factor inputs: labor, capital, and total factor productivity. Those inputs are cyclically adjusted (that is, purged of the influence of the business cycle) and then substituted back into the production function, yielding values of potential output. Historical values of potential output in the other sectors are computed directly by cyclically adjusting output in each sector.

The Nonfarm Business Sector

The heart of the growth model is a neoclassical production function that calculates GDP in the nonfarm business sector as a function of hours worked (labor), the capital stock, and total factor productivity in that sector. The production function is

(3) $$\log(GDP) = 0.7\times\log(L) + 0.3\times\log(K) + \log(TFP) + C$$

where GDP = real GDP in the nonfarm business sector,
L = hours worked in the nonfarm business sector,
K = capital input in the nonfarm business sector, lagged one year,
TFP = total factor productivity, and
C = a constant (constrains real GDP to equal nominal GDP in 1987).

The parameters of the production function (that is, the coefficients on labor and capital) represent the contribution to the growth of output made by the growth of labor and capital. CBO follows the literature on growth accounting in assuming that those coefficients can be approximated by the shares of labor compensation and capital income in the value of output.[6] For example, the payments to owners of capital in the United States are roughly 30 percent of total income. The growth-accounting framework therefore suggests that 1 percent growth in the capital stock leads to 0.3 percent growth in output.[7] Similarly, an increase of 1 percent in the growth of hours worked leads to an increase of 0.7 percent in the growth of output. After accounting for growth in labor and capital, any further growth in output is attributed to growth in total factor productivity, which is computed as a residual using equation (3).

An alternative method for determining the appropriate values of the coefficients is to use an econometric approach, which allows the data to determine the coefficients. CBO chose not to follow that approach, however, because the economic literature indicates that it creates more problems than it solves. In particular, econometric estimates of the coefficients of production functions are generally plagued by statistical problems, making their results suspect. The most serious problem affecting such estimates is a probable correlation between the explanatory variables (particularly capital) and the error term in the regression. Estimating a regression in the presence of such a correlation would result in biased coefficients.

Another problem is that in order to estimate the coefficients statistically, the capital input must be adjusted (over time) to reflect how intensively the capital stock is used. That adjustment introduces a source of measurement error because of the difficulty in accurately measuring the rate at which the capital stock is used. Since most analysts who use the econometric approach check to see whether their estimates

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6. This approximation follows from two common assumptions about the nonfarm business sector: that the production function displays constant returns to scale and that firms will attempt to maximize profits. Taken together, those assumptions imply that each factor's contribution to output will equal its share of total factor compensation. For a more complete discussion of economic growth and growth accounting, see Angus Maddison, "Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment," *Journal of Economic Literature*, vol. 25 (June 1987), pp. 649-698; Edward F. Denison, *Trends in American Economic Growth, 1929-1982* (Washington, D.C.: Brookings Institution, 1985); or Dale W. Jorgenson, Frank Gollop, and Barbara Fraumeni, *Productivity and U.S. Economic Growth* (Cambridge: Harvard University Press, 1987).

7. Other approaches suggest that capital's contribution to the growth of output is understated--perhaps greatly understated--by its share in total income. Recent theories of economic growth argue for a larger coefficient on capital, perhaps because of benefits that spill over from firms that add new capital to others that do not. However, the new theories are not well supported by empirical evidence and therefore have not been adopted by CBO in estimating potential GDP. See Congressional Budget Office, *Recent Developments in the Theory of Long-Run Growth: A Critical Evaluation,* CBO Paper (October 1994), for a survey of the new theories and evidence.

are reasonable by comparing them with income shares, the payoff to using the econometric approach is small.[8]

To compute potential output in the nonfarm business sector, CBO removes the influence of the business cycle from the labor input and TFP before using them in equation (3). Without that adjustment, the equation would merely compute historical values of actual rather than potential output. The capital input does not need to be adjusted because its potential value is similar to its actual value. The final form of the production function is

$$(3') \qquad \log(GDP^*) = 0.7\times\log(L^*) + 0.3\times\log(K) + \log(TFP^*) + C$$

where the variables are defined as they were in equation (3) and (*) denotes potential values.

CBO uses a simple regression equation to cyclically adjust the labor and productivity inputs.[9] Several components of CBO's model are cyclically adjusted using that equation, but it will be described only once, using the model's labor input as an example.

Labor Input. The labor input (L) in the production function--hours worked in the nonfarm business sector--displays marked cyclical fluctuation. The business cycle affects each of the components of hours worked: the labor force, employment, and average weekly hours. Each of those components could be cyclically adjusted separately, but CBO adjusts hours worked directly because the resulting series--potential hours worked--is nearly identical regardless of whether hours worked or its components are adjusted.

CBO's cyclic-adjustment equation rests on two assumptions: that an observable, exogenous benchmark exists that indicates when hours worked equals its potential level; and that potential hours worked follows smooth trends over time. CBO's benchmark is an estimate of the natural rate of unemployment, called the

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8. For examples of the econometric approach, see J.M. Perloff and M.L. Wachter, "A Production Function-Nonaccelerating Inflation Approach to Potential Output: Is Measured Potential Output Too High?" in Karl W. Brunner and Allan H. Meltzer, eds., *Three Aspects of Policy and Policymaking: Knowledge, Data, and Institutions,* Carnegie-Rochester Conference Series on Public Policy (Amsterdam: North-Holland Publishing Co., 1979), pp. 113-163; R.A. Raasche and J.A. Tatom, "Energy Resources and Potential GNP," *Review*, Federal Reserve Bank of St. Louis, vol. 59, no. 6 (June 1977), pp. 10-24; and Adams and Coe, "A Systems Approach to Estimating the Natural Rate of Unemployment."

9. CBO's procedure is similar to one developed by Peter Clark, who used it with real GNP to compute potential GNP directly. See P.K. Clark, "Potential GNP in the United States, 1948-80," *Review of Income and Wealth,* vol. 25, no. 2 (June 1979), pp. 141-165. For a survey of related methods, see Charles Adams, Paul R. Fenton, and Flemming Larsen, "Potential Output in Major Industrial Countries," *Staff Studies for the World Economic Outlook*, International Monetary Fund (August 1987), pp. 1-38.

nonaccelerating inflation rate of unemployment, or NAIRU. It corresponds to a particular notion of full employment: it is the rate of unemployment that is consistent with a stable rate of inflation.[10] The assumption of smooth time trends implies that potential hours worked grows at a constant rate over one or more prespecified historical periods.

The following equations provide the foundation for the cyclic-adjustment equation:

(4) $$\log(L/L^*) = \alpha(U - U^*) + \epsilon$$

(5) $$L^* = f(T_{1953}, T_{1957}, T_{1960}, T_{1969}, T_{1973}, T_{1980}, T_{1981})$$

where L = hours worked in the nonfarm business sector,
L^* = potential hours worked in the nonfarm business sector,
U = unemployment rate,
U^* = the NAIRU, and
T_i = the number of quarters elapsed since the peak in the business cycle occurring in year i.

Equation (4) relates the percentage difference between actual and potential hours worked to the difference between the actual unemployment rate and the NAIRU. This equation implies a stable relationship between the "hours-worked gap" and the "unemployment gap." In particular, if the unemployment rate is above the NAIRU, then hours worked is assumed to be below its potential level; higher rates of unemployment are associated with shorter work weeks, less overtime, and so forth. The reverse is true when the unemployment rate falls below the NAIRU.

Equation (5) restates the assumption that potential hours worked follows smooth trends over time. CBO does not constrain potential hours worked to follow a single time trend throughout the entire sample. Instead, the equation allows for several time trends, each beginning at the peak of a business cycle. Allowing for breaks in the trend implies that the rate of growth of potential hours worked is constant within each cycle but can differ from one business cycle to the next.

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10. The Bureau of Labor Statistics adopted a new survey to compute many variables in the labor market during the first quarter of 1994. The new survey was designed to measure more accurately the decisions women and part-time workers make about participating in the labor market and led to an upward shift in the measured rate of unemployment. Until enough new data are available to reestimate historical values of the NAIRU, CBO will rely on an adjustment to the NAIRU estimated using the old method. See Appendix B in Congressional Budget Office, *The Economic and Budget Outlook: An Update* (August 1994), for a description of the procedure used to estimate the NAIRU.

The cyclic-adjustment equation (6) results from combining equation (4) and equation (5).

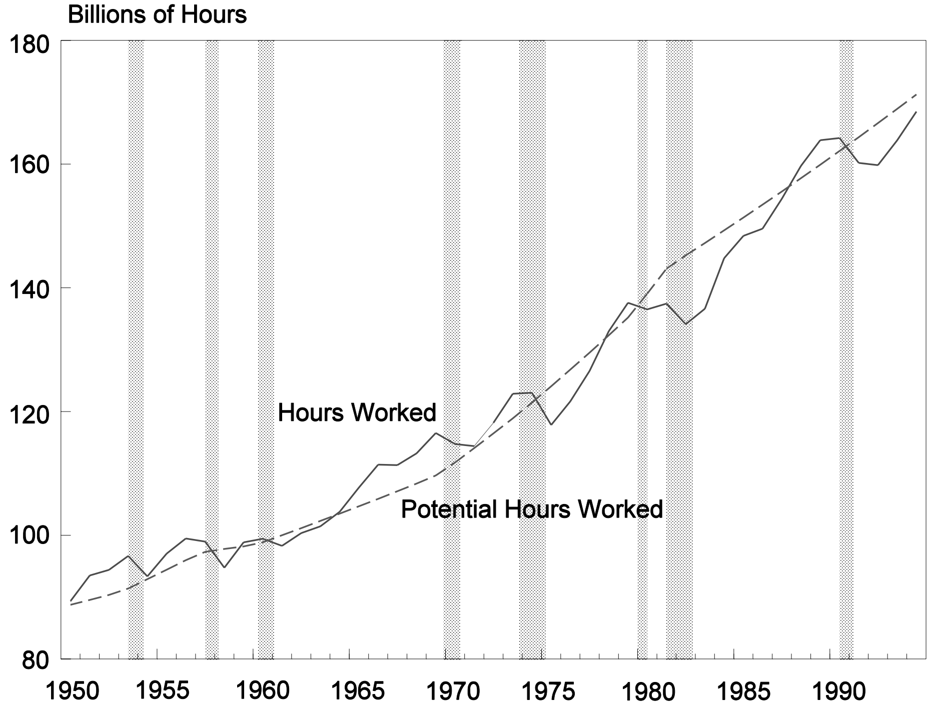
$$\text{(6)} \qquad \log(L) = \alpha(U - U^*) + f(T_{1953}, T_{1957}, T_{1960}, T_{1969}, T_{1973}, T_{1980}, T_{1981}) + \epsilon$$

The equation is estimated using quarterly data and ordinary least squares, a standard method of statistical estimation. Historical values of potential hours worked are calculated as the fitted values from the regression, with U constrained to equal U^*. Fitted values of the regression are estimated values of the dependent variable that are computed using historical values of the explanatory variables and the estimated coefficients of the regression. Setting the unemployment rate to equal the NAIRU removes the estimated effects of fluctuations in the business cycle; the resulting estimate gives the equation's prediction of what hours worked would be if the unemployment rate never deviated from the NAIRU (see Figure 1).

Capital Input. The growth model's capital input (K) is based on values of the net stock of capital in constant dollars, as published by the Bureau of Economic Analysis. However, using the net stock would give a misleading view of overall capital accumulation because it implicitly assumes that the productivities of different types of capital goods are identical, which they clearly are not. Therefore, the capital input in the growth model is an index that accounts for the fact that different types of capital assets (for example, equipment, structures, and inventories) have different marginal productivities.

This index measures the flow of capital services available for production. For example, holding the capital stock constant but shifting a dollar of investment spending to a more productive type of capital would increase the true level of capital services available for production. In that situation, CBO's measure of the capital input would grow but the unadjusted capital stock would not. This example is analogous to the U.S. experience during the past two decades: investment spending has shifted toward assets with higher marginal productivities. The share of investment devoted to producers' durable equipment (PDE) has risen while the share going to structures has declined, and a larger portion of equipment purchases has been devoted to computers.

FIGURE 1. HOURS WORKED AND POTENTIAL HOURS WORKED
(By calendar year)



SOURCE: Congressional Budget Office using data from the Department of Commerce, Bureau of Economic Analysis.

NOTE: Shaded areas denote recessions.

CBO uses a chain-weighted Tornqvist index to aggregate the individual types of capital in the nonfarm business sector. The equation is:

(7) $$\log(K_t/K_{t-1}) = \sum_i \omega_{i,t} \times \log(K_{i,t}/K_{i,t-1})$$

where $\omega_{i,t} = (s_{i,t} + s_{i,t-1})/2$,
$s_i = (r_{i,t}\, K_{i,t})/(\sum_i r_{i,t}\, K_{i,t})$,
$r_{i,t}$ = rental rate for asset i in year t,
$K_{i,t}$ = stock of capital asset i in year t, and
$K_{i,t-1}$ = stock of capital asset i, lagged one year.

The capital assets in equation (7) are the stocks of computer PDE, noncomputer PDE, nonresidential structures, and inventories, all in the nonfarm business sector. The growth of the capital input is a weighted average of the growth rates of the different capital assets, where the weights (ω_i) are functions of the relative cost shares (s_i) of each type of capital. (The relative cost shares are estimates of the share of total capital income "paid" to each type of capital.) The marginal productivity of each type of capital will be proportional to its relative cost share if two conditions apply: firms minimize their costs, and the "true" capital aggregator function displays constant returns to scale.[11] Thus, the overall index reflects the marginal productivities of the different types of capital being aggregated.

Unlike total capital income, the relative cost shares cannot be observed directly. However, they can be approximated using an estimate of the rental rate (r_i) for each type of capital: compensation paid to each type of capital would equal the stock of that type of capital multiplied by the corresponding rental rate. Rental rates are the "prices" that companies "pay" per period for the use of a capital asset. Those rates are directly analogous to wages, which are the prices paid per period for the use of the services of their employees. Rental rates can be observed for capital assets that are leased (structures, for example), but for most types of capital the rental rates must be inferred from the price of capital goods, the cost of capital (including both debt and equity), tax rates, and depreciation rules.

Unlike the labor input, the capital input does not need to be adjusted to its potential level, even though use of the capital stock varies greatly over the business cycle. Although the capital stock may be used more or less intensively, the potential

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11. Constant returns to scale is a property of some functions; it holds when a given percentage increase in the function's inputs (the different capital assets in this case) yields the same percentage increase in the function's dependent variable (the capital index). For more details, see M.J. Harper, E.R. Berndt, and D.O. Wood, "Rates of Return and Capital Aggregation Using Alternative Rental Prices," in D.W. Jorgenson and R. Landau, eds., *Technology and Capital Formation* (Cambridge: MIT Press, 1989); or W.E. Diewert, "Aggregation Problems in the Measurement of Capital," in Dan Usher, ed., *The Measurement of Capital* (Chicago: University of Chicago Press, 1980).

flow of capital services will always be related to the total size of the capital stock, not to the amount currently being used.[12]

Total Factor Productivity. Total factor productivity is computed as a residual--that is, the growth in output that remains after removing the growth in labor and capital. TFP is analogous to the more traditional concept of labor productivity; whereas labor productivity is defined as growth in output beyond growth in labor, TFP is defined as the growth in output that exceeds growth in both labor and capital.

Growth in TFP has proved to be a difficult variable for economists to explain, model, or predict. Although its growth is typically attributed to technological change, anything that causes output to grow faster (or more slowly) than the measured levels of its inputs will cause TFP to grow faster (or more slowly). Analysts have attributed growth in TFP to many causes in addition to technological progress: changes in the rate at which capital is used, changes in the quality of labor or the amount of human capital, spillovers from investments in capital, or shocks to productivity.[13] Note that all but the last two involve some kind of measurement error; a change occurs in the actual flow of labor or capital services that the traditional measures of capital and labor do not pick up.

Historical values of TFP are calculated by substituting actual historical values of output and the capital and labor inputs into equation (3). Like the labor input, TFP must be adjusted to its potential level before being used to compute potential output. That adjustment is made using equation (6).[14]

The Other Sectors

The method for computing historical values of potential output in the government, farm, and household and nonprofit institutions sectors differs slightly from that used

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12. Note that past fluctuations in the business cycle affect investment, capital accumulation, and potential output. Robert Coen and Bert Hickman compute a potential capital stock based on the pattern of investment that they estimate would have occurred if output had equaled potential output. See Coen and Hickman, *The Natural Growth Path of Potential Output*, Working Paper (Laxenburg, Austria: International Institute for Applied Systems Analysis, August 1980).

13. See Congressional Budget Office, *The Economic and Budget Outlook: Fiscal Years 1988-1992* (January 1987), for a nontechnical review of the factors that influence both labor productivity and total factor productivity. See also the symposium on the slowdown in productivity growth in *Journal of Economic Perspectives*, vol. 2, no. 4 (Fall 1988).

14. Before the method can be used, TFP must be recomputed on a quarterly basis. Data limitations prevent direct computation, so CBO interpolates the annual values to quarterly values by using the information contained in a related series that is available on a quarterly basis. The related series is the index of labor productivity in the nonfarm business sector, which is published by the Bureau of Labor Statistics.

for the nonfarm business sector. Instead of cyclically adjusting the factor inputs and substituting them into the production function, CBO computes potential output in the other sectors directly, using equation (6). Output in each of the other sectors is adjusted independently, using the same procedure. Output in the housing sector is not adjusted to potential because it is not influenced significantly by fluctuations in the business cycle.

Before the production function in equation (3) can be specified, output in the other sectors is removed from total GDP because different sectors have different methods of production and because some data are not available for some sectors. Excluding output in the other sectors from equation (3) ensures that the measure of output on the left-hand side of the equation and the factor inputs on the right-hand side are consistent. The following sections detail the differences between sectors.

Government Sector. The national income and product accounts measure output in the government sector as the total compensation (in constant dollars) of all employees in that sector.[15] Thus, no matter how the government actually produces its output, the way the data are measured constrains output to depend entirely on its labor input, with no contribution from government-owned capital. Specifying a neoclassical production function for this sector would therefore be inappropriate. Although the government sector is better insulated from the effects of the business cycle than the nongovernment sectors are, its output displays a mild positive correlation with the business cycle and therefore needs to be adjusted to potential.

Farm Sector. Although the production technology for output in the farm sector is likely to be similar to that of the nonfarm business sector, CBO models farm output separately. Farm output is quite volatile, varying for reasons (especially the weather) that have little to do with the size of its labor or capital inputs. In addition, the dramatic technological progress experienced in this sector during the postwar period makes it less comparable with the nonfarm business sector. Output in this sector is adjusted to potential using equation (6).

Households and Nonprofit Institutions Sector. The NIPAs measure output in this sector as the value of work supplied by people employed in private households, such as domestic workers, and in not-for-profit institutions. In each case, the value of the work supplied is measured as the sum of all compensation paid to employees, just as it is in the government sector. Thus, this sector must be modeled separately from nonfarm business output for the same reason as the government sector. Output in

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15. The Bureau of Economic Analysis computes the constant-dollar estimate of total compensation by extrapolating current-dollar compensation in the base year (1987) using indexes of employment and hours worked in the government sector. BEA attempts to control for education and experience, but within each category there is no change over time in output per hour worked; productivity can rise only if employment shifts to workers with more education or experience.

this sector is influenced by the business cycle and therefore must be adjusted to potential using equation (6).

Housing Sector. The NIPAs measure housing output as a stream of housing services that flows almost entirely from the capital input (the stock of residential housing), with virtually no contribution from labor. For that reason, and because housing output does not need to be adjusted to potential, CBO models this sector separately from the nonfarm business sector.

PROJECTING POTENTIAL OUTPUT

Before solving the growth model to calculate future values of potential output, CBO must project the model's exogenous variables, such as potential labor force, the rate of national saving, and potential total factor productivity. The projections of some exogenous variables are formed by extrapolating trends found in the historical data, and others are aligned with CBO's macroeconomic forecast.

The Nonfarm Business Sector

Potential output in the nonfarm business sector is projected using equation (3′), the same production function that is used to estimate historical values of that variable. Equation (3') combines projections of labor, capital, and total factor productivity.

Labor Input. To project the model's labor input--potential hours worked--CBO breaks it into its component parts. Merely extrapolating potential hours worked would be inappropriate because doing so would implicitly hold constant the growth of its components. If, as CBO expects, the growth of the labor force slows during the next decade, then extrapolating would overestimate the true series. CBO projects separately the four components of hours worked: the potential labor force, the NAIRU, potential employment in the sectors other than nonfarm business, and (at potential) average weekly hours worked in the nonfarm business sector.

The projections for the labor force and the NAIRU are based on projections made by the Bureau of Labor Statistics and the Social Security Administration. The projection for the potential labor force is computed from those agencies' projections of population and rates of labor force participation broken down by age and sex. The projection for the NAIRU also reflects demographic considerations. It combines projections of the shares of the labor force composed of each age/sex group with the historical estimate of the NAIRU for the same group. The growth model combines the projections for the potential labor force and the NAIRU to project potential employment using equation (8).

(8) $Empl^* = [1 - (U^*/100)] \times \text{labor force}^*$

where $Empl^*$ = potential employment,
U^* = NAIRU, and
Labor $force^*$ = potential labor force.

Potential employment in the nonfarm business sector equals total potential employment less potential employment in the other sectors. Potential employment in each of the other sectors is projected as a share of total potential employment. The shares are projected to continue their recent trends, with an adjustment, if necessary, to ensure consistency with CBO's assumptions about fiscal policy.

CBO projects the final component required for the projection of potential hours worked--average weekly hours in the nonfarm business sector (at potential)--by extrapolating its trend estimated during the recent historical period.

Capital Input. The primary advantage of using a growth model to project potential output is that the model projects the capital input using saving rates specified outside the model. Since the capital input in the model is calculated from the capital stock in the nonfarm business sector, its growth is fundamentally determined by the level of capital accumulation, or net investment. The model determines the level of gross investment as being equal to the level of national saving, which in turn equals the sum of private and government (federal, state, and local) saving plus foreign borrowing.

The levels of saving are set by the model using three prespecified rates of saving out of national income--one each for private, federal, and state and local government saving.[16] CBO develops the saving rates as part of its short-term macroeconomic forecast by analyzing patterns of income, consumption, investment spending, and fiscal policy. The rates are applied to the model's projection of national income to determine the level of saving, investment, and capital accumulation. Government saving comprises surpluses in federal as well as state and local budgets and is therefore the value directly affected by changes in fiscal policy. The model allows the user, for example, to adjust the federal saving rate to constrain the federal deficit to equal CBO's baseline projection.

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16. Since the rates of saving are set exogenously, the user of the model must determine whether an increase in government saving will be matched by a decrease in other components of national saving, in keeping with the doctrine of Ricardian equivalence. The model itself neither assumes nor precludes the existence of Ricardian equivalence. Although theoretically appealing, the empirical evidence supporting Ricardian equivalence is mixed. See Congressional Budget Office, *The Federal Deficit: Does It Measure the Government's Effect on National Saving?* (March 1990); or B. Douglas Bernheim, "Ricardian Equivalence: An Evaluation of Theory and Evidence," in Stanley Fischer, ed., *NBER Macroeconomics Annual: 1987* (Cambridge: MIT Press, 1987).

The capital input should be influenced only by the accumulation of capital in the nonfarm business sector, so the model includes only the parts of gross investment relating to that. Once gross investment has been set as being equal to national saving, the model determines fixed investment in the nonfarm business sector by subtracting from gross investment both fixed investment in the farm and housing sectors and changes in inventories. The remainder is then separated into investment in structures, computer PDE, and noncomputer PDE using shares that are consistent with CBO's short-term macroeconomic forecast. Those three categories constitute capital accumulation in the nonfarm business sector; equation (9) adds each category of investment to its corresponding capital stock after adjusting the stock for depreciation.

(9) $$K_{i,t} = (1-\delta_i)K_{i,t-1} + I_{i,t}$$

where $K_{i,t}$ = stock of capital asset i in year t,
δ_i = depreciation rate for asset i,
$K_{i,t-1}$ = stock of capital asset i, lagged one year, and
$I_{i,t}$ = investment in asset i in year t.

The capital stocks are then combined with the change in nonfarm inventories (computed as a function of real growth) to form the capital input, which is entered into the production function. The capital input is a weighted average of the rates of growth of its four components (structures, computer and noncomputer PDE, and inventories); the weights reflect the levels of productivity of each type of capital good, as shown in equation (7). Equipment, for example, has a higher marginal productivity than structures, so it receives greater weight in the capital input.

Total Factor Productivity. To project potential output, the growth model requires an independent projection of potential TFP. CBO currently projects potential TFP to grow 0.7 percent a year, which is its average rate of growth since 1981. By projecting potential TFP to follow that trend, CBO assumes that the forces that determine its growth will not change.[17] In particular, CBO assumes that TFP is not influenced by the model's assumptions about two key variables: the rate of investment and the growth of the labor input.

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17. Part of the growth in TFP experienced during the 1980s and 1990s can be attributed to the rapid increase in (measured) real investment and GDP caused, in part, by sharp declines in the price of computers. By assuming a constant trend, CBO is implicitly assuming that computer prices will continue their descent during the projection period.

The Other Sectors

CBO's growth model uses very simple production relationships to project potential output in the sectors other than nonfarm business. The model computes potential output in each sector as a function of one of the factor inputs in that sector and the average productivity of that factor. For all of the sectors except housing, the factor input is adjusted to potential. Potential output in each sector is projected by extrapolating trends found in the factor inputs and productivity.

Government Sector. The growth model determines potential output in the government sector as the product of potential hours worked and potential labor productivity (measured as output per hour) in that sector. Because government's output is measured as the total constant-dollar compensation of all government employees, the model constrains output to depend entirely on its labor input, with no contribution from capital. Both potential hours worked and productivity are projected to follow recent trends.

Farm Sector. The growth model projects potential farm output as the product of potential farm employment and productivity (measured as output per worker), assuming that both continue to grow at their recent rate of growth. Limitations of the data make it very difficult (and risky) to compute the capital stock or hours worked in the farm sector.

Households and Nonprofit Institutions Sector. The growth model's equation for potential output in this sector takes the same form as that of the government sector--the product of potential hours worked and potential labor productivity. As in the government sector, output is measured as the sum of all constant-dollar compensation paid to employees in the sector. Both potential hours worked and potential productivity are projected to continue their rate of growth since the early 1980s.

Housing Sector. Output in this sector, which is not adjusted to potential, is a function of the stock of residential housing. The model projects output in the housing sector as a fixed ratio to the housing stock, which in turn is a fixed ratio to a five-year moving average of real GDP.

The Foreign Sector

The growth model requires projections of net foreign investment and gross foreign product to project the capital stock in the nonfarm business sector and to compute GNP. Net foreign investment is the difference between gross domestic saving and gross domestic investment. If that number is negative, as it has been in recent years, then foreigners are supplying funds used for investment in this country. Gross domestic investment is therefore larger than it could be using only domestically supplied funds, allowing productive capacity to expand more quickly than it otherwise would. Negative net foreign investment also implies that the stock of foreign-owned U.S. assets is growing more quickly than the stock of U.S.-owned foreign assets (net foreign investment is the difference between the increments in those variables). The growth model computes the stock of U.S.-owned foreign assets and the level of net foreign investment as shares of GNP and then computes the stock of foreign-owned U.S. assets implied by the projections of the first two variables.

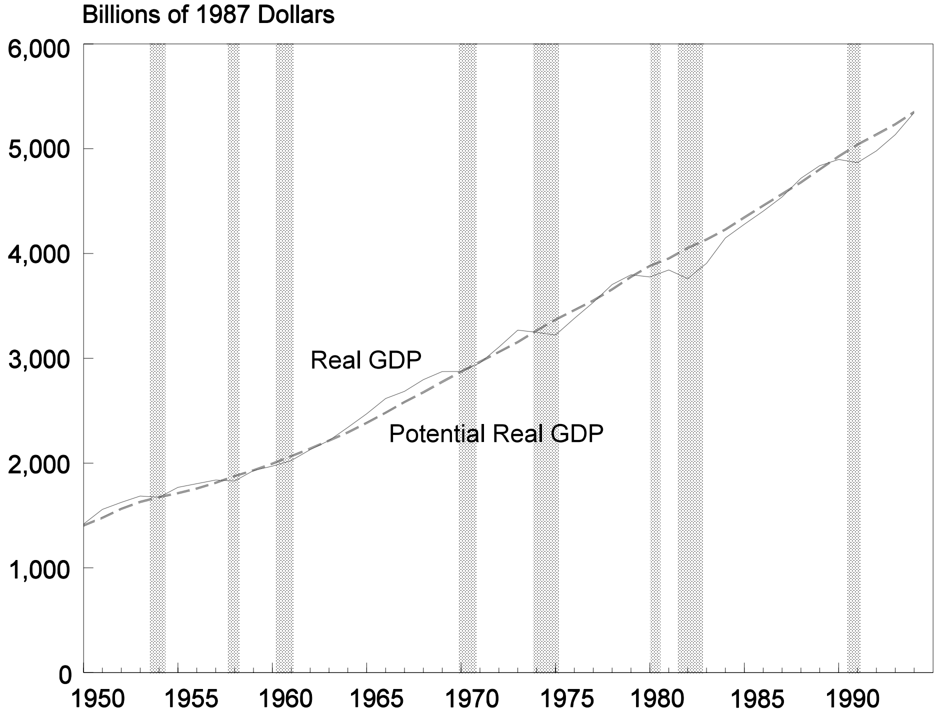
Gross foreign product is measured by U.S. receipts of factor income from foreigners less U.S. payments of factor income to foreigners, composed primarily of income from the stocks of foreign-owned U.S. assets and U.S.-owned foreign assets. The growth model projects gross foreign product by applying historical rates of return on those assets to the stocks of U.S.- and foreign-owned assets determined by the model, as described above.

CBO'S ESTIMATE OF POTENTIAL OUTPUT

Potential output provides a useful measure of capacity for the overall economy. Output generally falls below potential during recessions, remains below during recoveries and early expansions, and rises above potential during late expansions (see Figure 2). Such effects of the business cycle are shown most clearly by the GDP gap, which is the percentage difference between output and potential output (see Table 1). The GDP gap is particularly useful for estimating the degree of inflationary pressure in the economy. When output rises above potential, the rate of consumer price inflation will probably rise in the next year or two, in the absence of any shocks (see Figure 3). Similarly, when output falls below potential, price pressures ease and the rate of inflation tends to fall.

CBO's estimates of potential output and the GDP gap are roughly similar to estimates calculated by other agencies and private forecasters (see Figure 4). Although the levels of the series differ, the pattern of the business cycle is largely the same for all estimates. Therefore, estimates of inflationary pressure formed using the alternative estimates of potential output would not differ by very much. One exception is the estimates of Data Resources, Inc. (DRI) and the International Monetary Fund (IMF) for the late 1980s. In contrast to the other estimates, DRI's measure of potential output implies the existence of excess capacity and downward pressure on inflation during that period. The IMF's estimate implies the opposite--that the degree of inflationary pressure was significantly greater than that implied by the other estimates.

FIGURE 2. REAL GDP AND POTENTIAL REAL GDP (By calendar year)



SOURCE: Congressional Budget Office using data from the Department of Commerce, Bureau of Economic Analysis.

NOTE: Shaded areas denote recessions.

TABLE 1. POTENTIAL OUTPUT AND RELATED SERIES, CALENDAR YEARS 1950-2002

	Real Gross Domestic Product (Billions of 1987 dollars)		GDP Gap	NAIRU[a]
	Actual	Potential	(Percent)	(Percent)
		Historical Values		
1950	1,419	1,405	1.0	5.3
1951	1,558	1,479	5.4	5.4
1952	1,625	1,563	4.0	5.4
1953	1,685	1,629	3.5	5.4
1954	1,674	1,676	-0.1	5.4
1955	1,768	1,713	3.3	5.5
1956	1,804	1,757	2.7	5.5
1957	1,838	1,813	1.5	5.5
1958	1,829	1,875	-2.6	5.5
1959	1,929	1,931	-0.3	5.5
1960	1,971	1,995	-1.4	5.5
1961	2,024	2,066	-2.1	5.6
1962	2,128	2,138	-0.4	5.6
1963	2,216	2,215	0.2	5.6
1964	2,341	2,293	2.3	5.6
1965	2,471	2,384	3.9	5.7
1966	2,616	2,481	5.6	5.8
1967	2,685	2,582	4.0	5.8
1968	2,797	2,676	4.5	5.8
1969	2,873	2,775	3.4	5.9
1970	2,874	2,872	-0.1	5.9
1971	2,956	2,967	-0.4	6.0
1972	3,107	3,060	1.6	6.0
1973	3,269	3,155	3.7	6.1
1974	3,248	3,265	-0.5	6.2
1975	3,222	3,368	-4.4	6.2
1976	3,381	3,460	-2.3	6.2
1977	3,533	3,552	-0.5	6.3
1978	3,704	3,658	1.3	6.3
1979	3,797	3,777	0.5	6.3

(Continued)

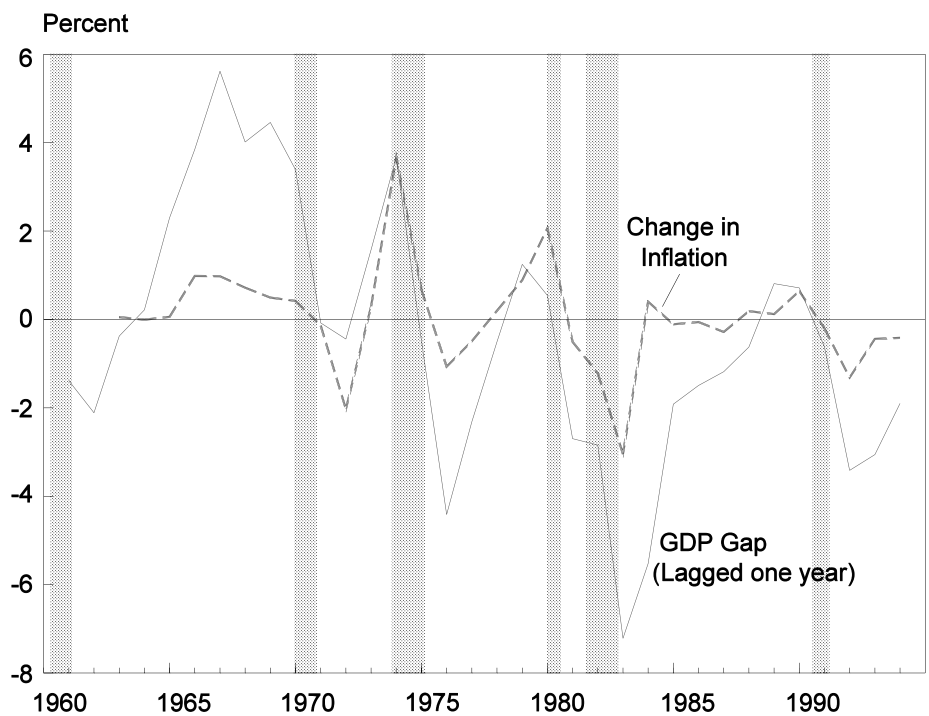
TABLE 1. CONTINUED

	Real Gross Domestic Product (Billions of 1987 dollars)		GDP Gap	NAIRU[a]
	Actual	Potential	(Percent)	(Percent)
	Historical Values (continued)			
1980	3,776	3,880	-2.7	6.3
1981	3,843	3,955	-2.8	6.2
1982	3,760	4,052	-7.2	6.2
1983	3,907	4,134	-5.5	6.1
1984	4,149	4,229	-1.9	6.1
1985	4,280	4,344	-1.5	6.1
1986	4,404	4,457	-1.2	6.1
1987	4,540	4,567	-0.6	6.0
1988	4,719	4,679	0.8	6.0
1989	4,838	4,803	0.7	6.0
1990	4,897	4,927	-0.6	5.9
1991	4,868	5,039	-3.4	5.8
1992	4,979	5,136	-3.1	5.8
1993	5,135	5,234	-1.9	5.8
1994	5,338	5,351	0	6.0
	Projections			
1995	5,505	5,491	0.1	6.0
1996	5,602	5,650	-0.4	6.0
1997	5,736	5,792	-0.4	6.0
1998	5,870	5,929	-0.4	6.0
1999	6,004	6,064	-0.4	5.9
2000	6,141	6,195	-0.4	5.9
2001	6,285	6,324	-0.4	5.9
2002	6,433	6,452	-0.4	5.9

SOURCE: Congressional Budget Office using data from the Department of Commerce, Bureau of Economic Analysis.

a. The NAIRU is the nonaccelerating inflation rate of unemployment. It is the benchmark for computing potential GDP. The increase in the NAIRU in 1994 stems from a change in the employment survey.

FIGURE 3. THE GDP GAP AND THE CHANGE IN INFLATION (By calendar year)

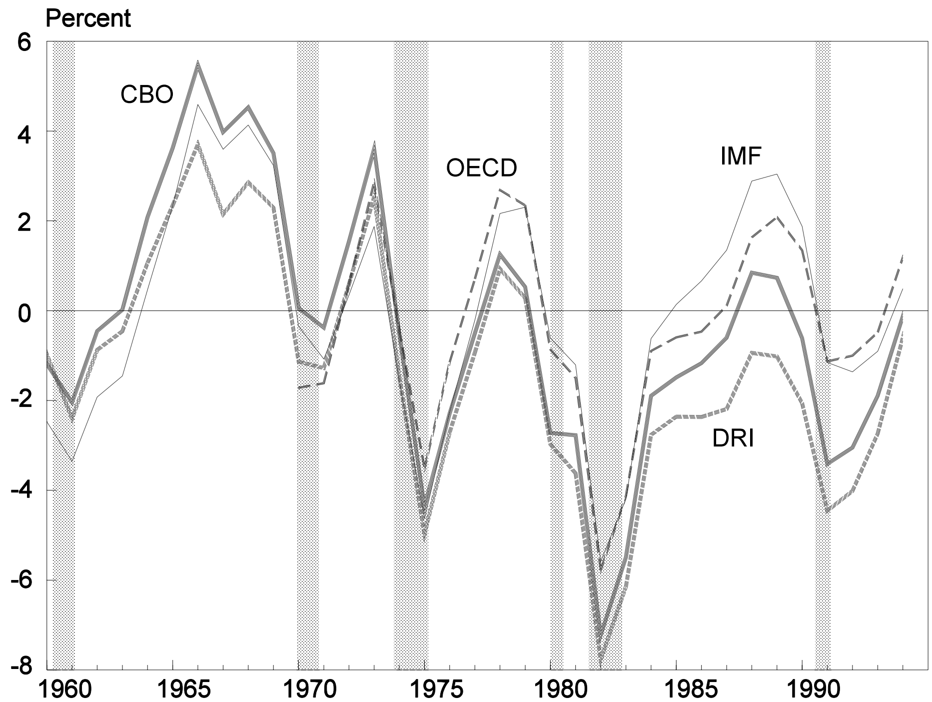


SOURCE: Congressional Budget Office using data from the Department of Commerce, Bureau of Economic Analysis, and the Department of Labor, Bureau of Labor Statistics.

NOTES: Inflation measured as the consumer price index for all urban consumers (CPI-U), excluding food, energy, and used cars.

Shaded areas denote recessions.

FIGURE 4. COMPARISON OF THE GDP GAP AS ESTIMATED BY CBO AND OTHER FORECASTERS (By calendar year)



SOURCE: Congressional Budget Office using data from the Department of Commerce, Bureau of Economic Analysis.

NOTES: OECD = Organization for Economic Cooperation and Development; IMF = International Monetary Fund; DRI = Data Resources, Inc.

Shaded areas denote recessions.

ADVANTAGES AND DISADVANTAGES OF THE GROWTH MODEL

The primary advantage of using a growth model to calculate potential output is that it explicitly includes capital as a factor of production. Therefore, it supplies a projection for potential output that is fully consistent with CBO's projection for the federal deficit, allowing CBO to incorporate the effects of changes in fiscal policy into its medium-term projection. Fiscal policy has obvious effects on aggregate demand in the short term, effects that CBO reflects in its short-term forecast. However, fiscal policy will also influence the growth in potential output over the medium term through its effect on national saving, and the growth model captures that effect.

CBO's growth model also provides a convenient framework for evaluating the effects of various policy changes on economic growth over the long term. The effects of deficit reduction are a good example of how the model can be used to conduct such policy simulations. CBO's current projection for potential output in 2002 is just under $6.5 trillion. That projection reflects CBO's baseline assumptions that gross private saving will average about 17 percent of potential (nominal) GDP during the 1996-2002 period and that the federal deficit will average 2.7 percent of potential GDP. If the Congress balanced the federal budget between 1996 and 2002, more than a trillion dollars would be added to the pool of national saving during that period. Although not all of that increase would be translated into gross investment, a reasonable estimate is that about 20 percent of it would be.[18] If so, then the capital stock would be about 2.2 percent greater than it otherwise would be in 2002, and potential output would be greater in that year by about 0.5 percent, or $32 billion. The projected changes in potential output would probably be matched by similar changes in the level of real GDP as well.

A second advantage of the growth model is its theoretical appeal. Potential output is a measure of productive capacity, so any such estimate ought to depend on all factors of production, including the capital stock. CBO's method should provide a more accurate view of potential output than other methods that depend on the labor input and ignore capital. Including capital also addresses the concerns of economists who argue that most of the year-to-year fluctuations in real GDP are caused by variation in aggregate supply factors rather than swings in economywide demand.[19]

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18. Deficit reduction is likely to lead to a decrease in U.S. borrowing from abroad and a decline in private saving. The size of those two offsets is a hotly debated topic among economists, with no clear consensus. However, a reasonable estimate of the decline in foreign borrowing would be 30 percent of the reduction in the deficit, and 20 percent would be reasonable for the drop in private saving.

19. Proponents of real business cycle models--so called because they focus on economic fluctuations that result from "real" forces, such as aggregate supply factors, rather than nominal variables, such as the money supply--make this argument. See the symposium on real business cycles in *Journal of Economic Perspectives*, vol. 3, no. 3 (Summer 1989). Empirical studies suggest that at short horizons (less than three years), most of the variation in output can be attributed to fluctuations in overall demand. As the horizon examined increases, so does the share of the variation

(Aggregate supply refers to the factors that determine the productive capacity of the economy, such as productivity, resource endowments, and labor supply.)

Adding the capital stock confers a practical benefit as well: it allows CBO to incorporate the future effects of short-run changes in economic growth on potential output. For example, slower growth not only depresses current output but also tends to limit future growth: there will be less investment in physical capital, less training, and so on. By explicitly including the accumulation of capital, the growth model captures part of those effects whereas the method that relies only on the unemployment gap does not.

Third, the growth model has a high degree of disaggregation, which reveals more insights about the economy than a more aggregated model would. For example, the model calculates the capital input to the production function as a weighted average of structures, computer PDE, noncomputer PDE, and inventories. Those data indicate a shift over the past few decades to capital goods with shorter service lives: a larger share of total fixed investment is going to PDE relative to structures, and a larger share of PDE is going to computers. Since shorter-lived capital goods have higher depreciation rates, the shift toward PDE and computers increases the share of investment dollars used to replace worn-out capital and tends to lower net investment and the capital input. Shorter-lived capital goods are also more productive than those with longer service lives and are therefore weighted more heavily in the growth model's capital aggregate. A model that ignores the capital input or one that does not disaggregate capital is likely to miss both of those effects.

A final advantage of using a growth model is that it relies less on fixed time trends than do many other methods of estimating potential output. A very simple method of estimating potential output is to adjust real GDP to potential directly, using an equation like equation (6). Indeed, CBO used that procedure before switching to the growth model. Although that method has the advantage of simplicity, it implicitly applies time trends to every component of GDP. In contrast, CBO's growth model avoids applying time trends to several components of GDP--in particular, the capital stock and output in the housing sector.

Reducing the reliance on fixed time trends is desirable because such trends may provide a misleading view of the cyclical behavior of some economic data series. Some analysts argue, based on empirical studies of the business cycle, that using variable rather than fixed time trends is more appropriate for most economic

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that is attributed to fluctuations in aggregate supply. See, for example, Olivier Blanchard and Danny Quah, "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review*, vol. 79, no. 4 (September 1989).

data series.[20] They assert that a trend should not be represented as a fixed rate of growth (say, 2 percent a year) but instead as a fixed rate of growth plus or minus some random amount, which could differ from year to year.

Analysts have proposed several alternatives to fixed trends, including centered moving averages, the Hodrick-Prescott filter, the Kalman filter, and econometric approaches such as vector autoregressions.[21] CBO chose not to adopt an alternative detrending method because the empirical evidence in favor of variable trends is not conclusive and because the suggested remedies all have significant drawbacks. For example, most of the alternatives require subjective decisions by the user about a model's structure or the values of parameters, and some perform poorly at the beginning or end of the sample period (by losing observations or losing the ability to identify the trend). Most important, many of the alternative methods do not benchmark their trend to any exogenous measure of capacity. Therefore, unlike CBO's results, the results of those methods cannot be interpreted as potential output.

The primary disadvantage of using a growth model is that including the capital stock introduces measurement error. Most economic variables are subject to measurement error, but the problem is particularly acute for capital.[22] First, settling on an appropriate definition for, and then measuring, economic depreciation is extremely difficult. Businesses' purchases of plant and equipment can be tallied to produce a historical series for investment, but no corresponding data source exists for depreciation, which is the decline in the efficiency of capital resulting from scrappage or wear and tear. CBO uses depreciation data from the NIPAs, which the Bureau of Economic Analysis estimates based on assumptions about service lives and efficiency patterns for different types of capital.

Measurement error can also arise when constructing the capital input, even if the capital stocks and depreciation are measured without error. The problem is that there are many types of capital goods, each with different fundamental characteristics such as productivity and durability. The heterogeneity of capital means that merely summing the stocks would give a misleading view of the level of capital services available for production. Economic theory provides an approach to the problem of aggregating capital--embodied in equation (7)--but the assumptions that underlie the equation may not be satisfied in practice. Compounding the aggregation problem is

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20. For a survey, see James H. Stock and Mark W. Watson, "Variable Trends in Economic Time Series," *Journal of Economic Perspectives*, vol. 2, no. 3 (Summer 1988), pp. 147-174.

21. See Ray Barrell and James Sefron, "Output Gaps: Some Evidence from the UK, France, and Germany," *National Institute Economic Review* (February 1995), pp. 65-73.

22. For more details on measurement error, see Charles R. Hulten, "The Measurement of Capital," in E.R. Berndt and J.E. Triplett, eds., *Fifty Years of Economic Measurement* (Chicago: University of Chicago Press, 1990).

the vast number of capital goods used in the nonfarm business sector; including every type of capital separately in the equation would be impractical if not impossible.

Another disadvantage is the degree to which the growth model's projection for potential output is sensitive to its independent assumptions, especially those about total factor productivity and national saving. The model's projections are affected directly by the projection for TFP and indirectly by the assumed rate of national saving (through its impact on capital accumulation). The projections for both variables are subject to change when either new data or revisions to previously available data are released. Experience shows that changes in either variable, when cumulated over CBO's 10-year projection horizon, can have large effects on the level of potential output.

For example, CBO currently projects that growth of potential TFP will average 0.7 percent a year between 1996 and 2002 and that potential output, measured in 1987 dollars, will grow 2.4 percent a year during the same period. That rate of growth leaves potential output at $6.48 trillion in 2002. If growth in TFP averaged just one-tenth of a percentage point higher--or 0.8 percent annually--then potential output would grow at 2.5 percent a year, boosting the level of the series in 2002 by $45 billion, to $6.52 trillion, or 0.7 percent above the baseline.

Finally, the model does not contain explicit channels of influence for all possible effects of fiscal policy on potential output. For example, the model includes no explicit link between tax rates and labor supply, productivity, or the personal saving rate. However, that does not mean that the model precludes a relationship between any of those variables. If a given policy change is estimated to be large enough to affect the incentives governing work effort, productivity, or saving, then including the effects in a projection or policy simulation is a straightforward task.