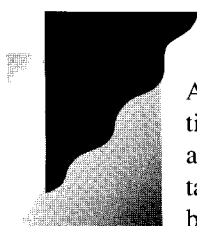


Monetary policy with uncertain estimates of potential output

Kenneth Kuttner



After years of neglect, potential output has drawn renewed attention as an input to monetary policy, appearing in a broad range of recent Federal Reserve system and academic research.¹ At one level, it is the *raison d'être* of an activist monetary policy. If potential output measures the economy's capacity to produce goods and services without adding to inflationary pressures, the goal of a stabilization policy should be to keep the economy operating as close to potential as possible.

While its significance is widely acknowledged, there is little agreement on the best measure of potential output. Until it was discontinued ten years ago, the series maintained by the Council of Economic Advisors (CEA) and published in the *Economic Report of the President* was probably the most prominent; since then, a number of competing measures have appeared. The first section of this article discusses in greater detail what it is that potential output is supposed to measure, and reviews some of the estimates in current use.

The next section discusses a new technique for estimating potential output. This method differs from existing measures by explicitly modelling potential real GNP as an unobservable variable, using data on output growth and inflation to infer its level. It also offers two significant advantages over existing measures. First, because it is defined in terms of inflation, it is not vulnerable to the structural changes in the labor market that have distorted measures

based on the unemployment rate. Second, it provides a way to calculate the uncertainty associated with the estimate, which is particularly important to policymakers charged with keeping output at or near potential. The final section of the article highlights the practical implications of this uncertainty and examines its role during the rapid expansion of 1988-89.

What is potential output?

In broadest terms, potential output is a measure of the economy's overall productive capacity, or its equilibrium level of output. In other words, potential output is supposed to summarize the state of the supply side of the economy, whose main determinants are labor, capital, and productivity. Fluctuations in these and other supply side factors—oil prices, for example—all contribute to variation in the growth of potential output through time.

In contrast to supply shocks, which affect potential as well as actual output, demand shocks alter the economy's status *relative* to potential. Examples include monetary and fiscal policy, as well as exogenous changes in consumption, investment, or demand for U.S. exports. Insufficient aggregate demand may result in a level of output at which factors of production are less than fully employed; similarly, excess aggregate demand may temporarily lift the economy above its equilibrium level

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of output. This taxonomy of shocks in terms of supply or demand suggests defining potential output as full-employment production, corresponding to the real GNP the economy would produce in the absence of demand shocks. In other words, with the economy operating near potential, labor and capital will be utilized as fully as possible, given any supply side constraints.²

An alternative but complementary definition of potential output exploits the link between output and inflation embodied in the aggregate supply curve. The aggregate supply function describes a positive relationship between levels of real output and the inflation rate, much as the well known Phillips Curve describes the negative correlation between the unemployment rate and inflation. However, it has long been recognized that this output-inflation tradeoff works only in the short run; that is, in the long run, the aggregate supply curve is vertical. Therefore, a stable inflation rate—one that is neither increasing nor decreasing—is possible only with output equal to potential.

This connection between potential output and a stable inflation rate inspired Arthur Okun's (1970) definition, in which potential output is the "maximum production without inflationary pressure, ... or more precisely ... the point of balance between more output and greater stability."³ So long as there is a stable relationship between employment (or capacity utilization) and inflation, this noninflationary characterization of potential output is compatible with its definition as full-employment output. Conceptually, defining potential output in terms of stable inflation simply shifts the focus from its underlying determinants to its inflationary implications. At a practical level, the link between potential output and stable inflation provides the foundation for the potential output measure discussed in this article.

Although potential output is sometimes associated with a simple trend line fitted to real GNP, nothing in either of these alternative definitions implies that the growth rate of potential output remains constant over time. The source of this perception is that throughout much of the 1960s, a log-linear trend was widely used as a proxy for potential output. As described below, events of the 1970s demonstrated that the straight-line method was satisfactory only in the absence of any significant

supply shocks. Since then, much of the research on potential output has focused on capturing the time-variation induced by aggregate supply shifts.

An aside on classical versus traditional perspectives on potential output

Not all economists agree that it makes sense to describe business cycles in terms of departures from potential output, a disagreement that surfaces in well known recent intermediate level macroeconomics textbooks. A discussion of potential GNP appears prominently in the introduction to Dornbusch and Fischer's (1990) book, whose view is consistent with the description of potential output sketched above. By contrast, the subject receives no mention at all in Barro's (1990) text.

Barro's omission of any discussion of potential GNP reflects the New Classical approach to business cycles, as embodied in the Real Business Cycle (RBC) theory pioneered by Kydland and Prescott (1982).⁴ RBC theory asserts that economic fluctuations are the outcome of competitive equilibria in which wages and prices adjust rapidly to clear all markets. According to this view, supply shocks (usually labelled technology shocks) are the sole source of fluctuations in *real* economic variables, such as output and employment. Demand shocks typically affect only *nominal* variables—the aggregate price level, for instance—without affecting relative prices, real output, or employment.⁵ According to the RBC view, therefore, it makes no sense to distinguish between actual and full-employment output. With output determined entirely by the supply side of the economy, potential output is simply equal to actual output.

The policy implications of RBC theory are far reaching. In these models, discretionary monetary policy can play no useful role in stabilizing the economy, as the only effect of monetary policy is on the price level. Furthermore, because the economy's fluctuations result from competitive equilibria, they are economically efficient.⁶ Therefore, even in those models in which monetary policy *can* affect real variables, doing so will typically reduce overall welfare.

Clearly, a pure RBC framework has no place either for estimating potential output, or for using it as a guide to macroeconomic policy. Instead, viewing business cycles as depart-

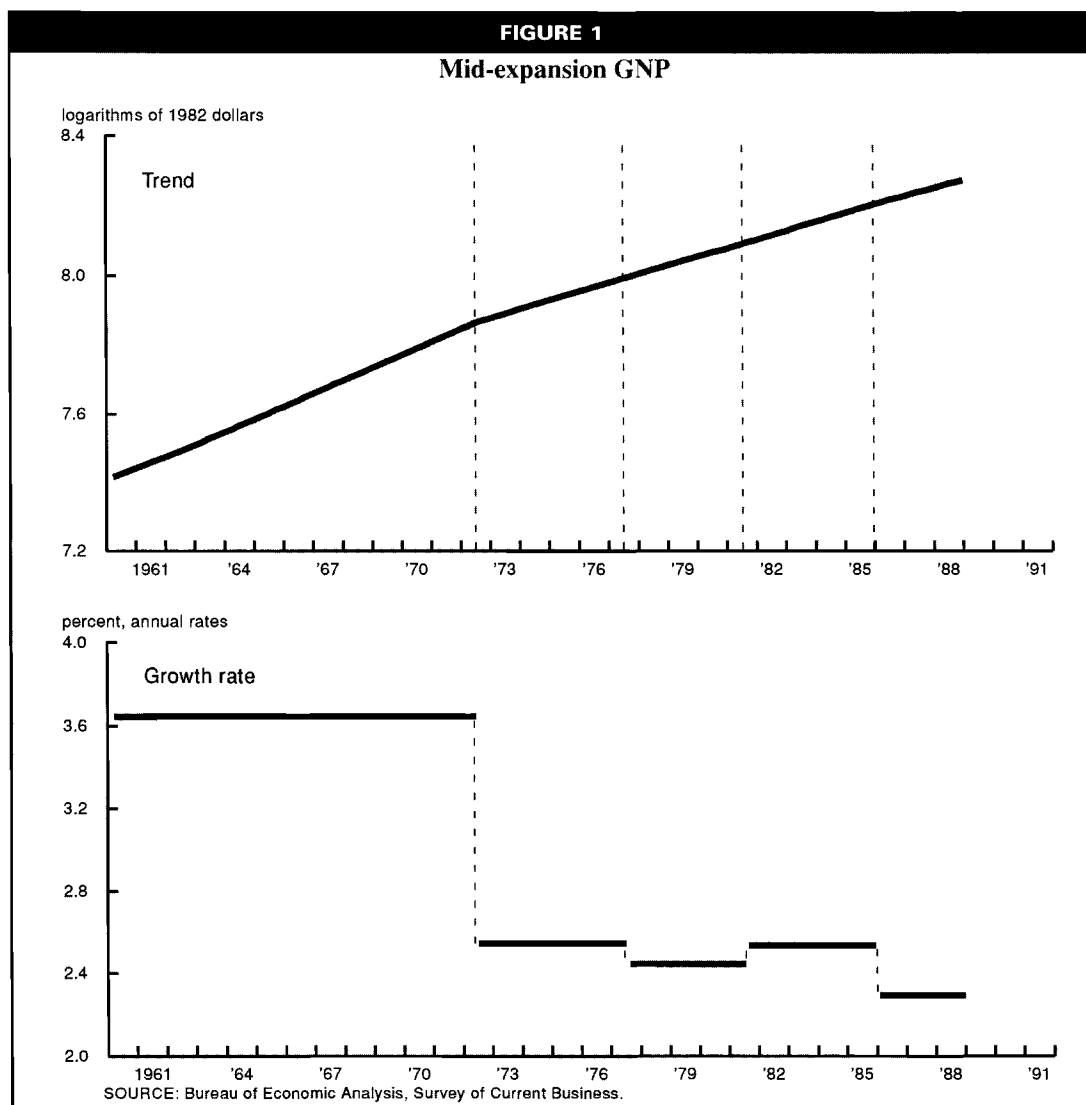
tures from potential output is much more consistent with the so-called traditional approach to macroeconomic fluctuations sketched earlier.⁷ Although the methodological differences between the traditional and the classical views are deep, RBC models have had a major impact on research that follows the traditional approach primarily by demonstrating the importance of supply shocks as a source of business cycle fluctuations. The new measure of potential output discussed in this article takes this proposition seriously, and seeks to quantify the relative importance of supply and demand factors.

Existing measures of potential output

Most existing measures of potential GNP have relied on one or more of the following techniques: segmented trends, supply-side

analysis, or Okun's law. Of the three, the segmented trend technique is perhaps the simplest. Typically, this involves drawing straight line segments through a plot of (log) real GNP. Giving each line segment its own slope is a simple way to capture local variations in the trend growth rate.

A key distinction among segmented trend measures lies in the choice of the segments' endpoints. One well known example is the mid-expansion GNP series published by the Bureau of Economic Analysis (BEA),⁸ plotted in the top panel of Figure 1. (The series is plotted on a logarithmic scale.) As the name implies, the segments' endpoints are the mid-points of business cycle expansions, whose dates are determined *ex post* by the National Bureau of Economic Research. The lower



panel of Figure 1 plots the annualized growth rate of mid-expansion GNP, whose stairstep appearance is due to the segmented trend construction of the series.

The supply-side analysis that was the basis for the discontinued CEA estimate is conceptually much more sophisticated than the mid-expansion series.⁹ This method gauges potential output by way of an aggregate production function relating factor inputs—labor and capital—to real output. Potential output is then determined by substituting the full-employment values of labor and capital into the production function. The main drawback to this technique is its formidable data requirements. Because quarterly capital stock figures are so unreliable, implementations of this method usually focus on labor inputs. Even so, it requires data on cyclically adjusted employment, hours, labor force participation rates, and productivity to construct its estimate of full-employment output. The Boschen and Mills (1990) series is a related measure which attempts to capture the supply-side effects of oil price shocks and changes in individuals' marginal tax rates.

The third commonly used technique is based on Okun's celebrated law, which uses the unemployment rate as a proxy for the gap between potential and actual output. With U denoting the unemployment rate, and letting GNP^* and U^* represent potential real GNP and the natural rate of unemployment respectively, Okun's law,

$$(1) \quad GNP^* = GNP \cdot [1 + 0.03 (U - U^*)],$$

states that the percentage deviation of GNP from potential is proportional to the gap between unemployment and the natural rate. The coefficient of 0.03 means that a 1 percent unemployment gap corresponds to a 3 percent gap between real GNP and potential. If the natural rate is known (Okun assumed it was 4 percent) this equation easily delivers an estimate of potential GNP. During the economically quietest 1950s and 1960s, a log-linear trend produced estimates of potential output nearly identical to those generated by Okun's law with U^* equal to a constant 4 percent. In fact, because it produced a smoother series, Okun recommended using the trend method as an alternative to the above equation.

The events of the 1970s—the oil shock, the 1974-75 recession, and the productivity slow-

down—contributed to the breakdown of a variety of potential output measures. The disintegration of measures based on Okun's law with a fixed natural rate of unemployment was especially conspicuous. With unemployment rates well above 4 percent, these measures indicated that output was far below potential, yet inflation continued to rise. The usual measures of potential output no longer seemed to correspond to stable inflation leading some, notably Gordon (1975), to use alternative time-varying measures to explain the behavior of inflation.

The deterioration of Okun's law can be traced to growth in the ranks of the *structurally* unemployed: workers who, because of structural change in the economy, had to retrain or relocate in order to find new employment. In response to the rise in structural unemployment, economists revised their conception of full employment, and the language used to describe it. The awkward phrase "nonaccelerating inflation rate of unemployment" replaced "natural rate," avoiding the implication that stable inflation was necessarily associated with a low unemployment rate. Likewise, the BEA switched to what it called a "high-employment benchmark" rate of unemployment, equal to 6 percent.

This experience exposed the Achilles' heel of Okun's law as a foundation for potential output: the unobservability of the time-varying natural rate of unemployment. If U^* is neither fixed nor observable, Okun's law merely describes a relationship between two unobservables, and cannot be used by itself to compute potential GNP; only in conjunction with some independent measure of the natural rate of unemployment will it yield an estimate of potential output.

The potential GNP series proposed by Clark (1983) and Braun (1990) are two recent examples of measures based on independent estimates of the natural rate of unemployment. Braun's series is actually a hybrid measure, combining an Okun's law equation with a segmented trend specification for potential output. Like other segmented trend measures, it also relies on some prior determination of the appropriate dates for trend breakpoints.¹⁰

Two-sided versus one-sided estimates

One essential distinction between these alternative techniques is the degree to which they rely on *ex post* information, that is, whether they are constructed contemporaneously or

retrospectively. An estimate of a given quarter's level of potential GNP is *one-sided* if it utilizes only data available in that quarter. A *two-sided* estimate, on the other hand, incorporates data that become available later. For instance, an estimate of 1990:4 potential that used 1991:1 inflation would be two-sided; one that relied only on data through 1990:4 would be one-sided. In other words, one-sided esti-

mates use only current and lagged data, while two-sided estimates use both lags and leads.

The BEA's mid-expansion trend GNP is a good example of an explicitly two-sided measure. Because business cycle peaks are dated well after the fact, the expansion's midpoint can be determined only retrospectively—obviously too late to be of any use for a policy designed to avert a recession. To produce a

An econometric model of potential output

The potential output measure proposed in Kuttner (1991) builds on a statistical technique known as a dynamic factor or multiple-indicator model. The basic idea behind these models is to describe the behavior of the observable data in terms of some underlying, unobserved variable. In this application, potential output is the key latent variable; inflation and real growth data are used as indicators of the unobserved level of potential output.

Let x_t represent the natural logarithm of real GNP at time t , and let e_t^d denote a period t shock to real GNP that does not affect potential output, denoted by x_t^* . The Greek letter Δ is the first-difference operator, so that $\Delta x_t = x_t - x_{t-1}$. The first component of the multiple-indicator model is the error-correction equation for real output,

$$(1) \quad \Delta x_t = a_0 + a_1(x_t^* - x_t) + a_2 x_{t-1} + a_3 x_{t-2} + e_t^d + a_4 e_{t-1}^d,$$

where a_0 through a_4 are coefficients to be estimated. If a_1 is positive, x_t^* in excess of x_t implies higher than average future real growth rates (subject to the distributed lag captured by the $a_2 \Delta x_{t-1}$ and $a_3 \Delta x_{t-2}$ terms, and the current and lagged shocks $e_t^d + a_4 e_{t-1}^d$). In this way, output tends towards potential over time, unless perturbed by e_t^d shocks.

The model's second building block is the inflation equation, based on a simple dynamic aggregate supply relationship reflecting the link between potential output and stable inflation. The change in the inflation rate is proportional to the gap between actual and potential output: GNP in excess of potential implies rising inflation, while falling inflation is a symptom of GNP below potential. The growth rate of M2 is allowed to exert an independent effect on the inflation rate. Using π_t to represent the current inflation rate, and letting m_{t-1} and p_{t-1} represent the lagged logarithms of M2 and the price level, the following equation embodies this output-inflation relationship:

$$(2) \quad \Delta \pi_t = b_1(x_{t-1} - x_{t-1}^*) + b_2(x_{t-2} - x_{t-2}^*) + b_3 \Delta(m_{t-1} - x_{t-1} - p_{t-1}) + e_t^\pi + b_4 e_{t-1}^\pi,$$

which includes a moving-average error term, $e_t^\pi + b_4 e_{t-1}^\pi$. The $m_{t-1} - x_{t-1} - p_{t-1}$ term, recognizable as the lagged logarithm of the inverse of M2 velocity, captures the direct effect of money stock changes on the price level.

Having described the link between the unobserved level of potential output and observed realizations of real output growth and inflation, it remains only to specify how potential output, x_t^* , evolves over time. The multiple indicator model replaces the traditional segmented trend with a more flexible stochastic trend specification discussed in Stock and Watson (1988). This specification says that over the long run, output will grow at some average rate, labelled g . However, shocks to potential output, e_t^* , can cause potential output growth to deviate from its mean. Moreover, these shocks are persistent with respect to the level of potential output: once perturbed by an e_t^* shock, x_t^* will show no tendency to return to its trendline. Plotting it alongside a deterministic trend with slope equal to g , the stochastic trend will appear to wander.

The mathematical expression of the stochastic trend specification is a random walk with drift:

$$(3) \quad x_t^* = g + x_{t-1}^* + e_t^*$$

The intercept g is the "drift" term in the random walk, corresponding to the long run growth rate of output. The unit coefficient on lagged x_t^* makes (log) potential output a random walk. By constraining the coefficient a_0 in Equation 1 to equal $g(1 - a_2 - a_3)$, real output is forced to grow at the same rate as potential on average.

The practical advantage of the stochastic trend assumption is to allow smooth variations in the growth rate of potential output unlike the segmented trend with its discrete kinks. While some research has endowed the random walk specification with a deeper economic interpretation, it was chosen for this application as a convenient way to pick up low-frequency time variation in the underlying trend.

One attractive interpretation of the overall model is in terms of supply and demand shocks, along the lines sketched earlier. The notation used here is consistent with this interpretation: the e_t^* in Equation 3 represent supply shocks, affecting the economy's underlying capacity to produce goods and services without additional inflationary pressure. Similarly, the e_t^d shocks in Equation 1 are disturbances to aggregate demand, which can deflect the economy's convergence to potential output.

Two specific features of this interpretation deserve special note. First, the supply shocks are assumed to

contemporaneous estimate would involve departing from the mid-expansion definition in some way, such as extrapolating the local trend from the previous reference cycle. Most segmented trend estimates share this two-sided property, as it usually takes several years of data to discern a change in the economy's underlying growth rate.

Other techniques can yield either one- or two-sided estimates. As described above, the

simple procedure using Okun's law with a constant natural rate of unemployment is one-sided. By contrast, the technique described in Clark (1983) is two-sided, utilizing leads as well as lags of the gap between unemployment and a time-varying natural rate.

Frequently, the benchmark natural unemployment rate used as an input to Okun's law is itself two-sided. Estimates of potential output

have permanent effects on the economy's productive capacity, while the demand shocks' impact is purely transitory. This distinction reflects the implications of the natural rate hypothesis introduced earlier, in which changes in aggregate demand have no lasting effects on real variables. Second, the combination of the stochastic trend and error-correction specifications of Equations 1 and 3 allows supply shocks to generate business cycle behavior. In other words, demand shocks are not the sole cause of output gaps; some fluctuations of output around potential are attributable to the dynamics of adjusting to a new equilibrium level of output.

Estimating the model

If data on x_t^* existed, one could easily estimate Equations 1 and 2 with the familiar linear regression technique. What complicates matters here is the fact that the key right-hand-side variable, $(x_t^* - x_t)$, is unobservable. One technique that makes it possible to estimate models with unobserved independent variables is the recursive Kalman filter algorithm.¹ Essentially, this algorithm uses the law of motion for potential output in Equation 3 to compute its optimal guess of the unobserved x_t^* . In the next step, it uses that guess in Equations 1 and 2 to generate one-quarter-ahead predictions for $\Delta\pi$ and Δx . The equations' fit is gauged by comparing these predictions to the actual data. A maximum-likelihood routine is then used to determine the coefficients that yield the best predictions. A by-product of this process is an estimate of the unobserved x_t^* series, based on the observable output growth and inflation data and the best-fit coefficients from Equations 1-3.

Table 1 displays estimates of Equations 1-3, fitted to quarterly data from 1960:1 through 1991:3. In

Equation 1, the coefficient of 0.11 on $(x_t^* - x_t)$ means that in the absence of any shocks, output will gradually converge to potential at a rate of 11 percent per quarter. However, this adjustment is interrupted by demand shocks with a standard deviation of 0.95 percent per quarter, or almost four percent in annualized terms. In Equation 2, the statistically significant coefficients on the two lags of the output gap are consistent with a strong relationship between aggregate demand and inflation. Similarly, M2 growth (less nominal output growth), appears as a significant additional determinant of inflation. The intercept in Equation 3, which represents the mean quarterly growth rate of potential output, is consistent with an average annual growth rate of roughly 3 percent. The magnitude of the persistent shock to potential output, as measured by its standard deviation, is similar, endowing the potential output series with a relatively large amount of time variation.

¹The Kalman filter technique is discussed in many time-series econometrics texts, including Harvey (1981).

TABLE 1

Estimates of the parameters of the potential output model

Output growth equation (1)	Standard deviation of $e^d = 0.943$
$\Delta x_t = 0.36 + 0.11(x_t^* - x_t) + 0.45 x_{t-1} + 0.20 x_{t-2} + e_t^d - 0.17 e_{t-1}^d$	
(0.05) (0.30) (0.15) (0.31)	
Inflation equation (2)	Standard deviation of $e^\pi = 0.254$
$\Delta \pi_t = 0.12 (x_{t-1}^* - x_{t-1}) - 0.10 (x_{t-2}^* - x_{t-2}) + 0.06 \Delta(m_{t-1} - x_{t-1} - p_{t-1}) + e_t^\pi - 0.70 e_{t-1}^\pi$	
(0.03) (0.03) (0.03) (0.23)	
Potential output equation (3)	Standard deviation of $e^s = 0.702$
$x_t^* = 0.75 + x_{t-1}^* + e_t^s$	
(0.07)	

NOTES: The sample is 1960:1 through 1991:3.

The data are expressed as quarterly percent growth rates.

The numbers in parentheses are estimated standard errors.

based on such measures should therefore be classified as two-sided, even when they use only current and lagged values of the unemployment gap. Rissman's (1986) time-varying estimate of structural unemployment is a good example, as it uses leads and lags of employment growth dispersion. Similarly, the common supply-side measures could fall into either of these two categories, depending on whether they used one- or two-sided methods to cyclically adjust the factor input data.

One area where the two- versus one-sided distinction is key is in the formulation of a policy feedback rule. Some economists, Taylor (1985) for example, have proposed versions of monetary policy rules in which the Federal Reserve would target the gap between real GNP and trend, or potential GNP. To achieve an appropriate balance between inflation and output goals, the output gap target would be subject to feedback: adjusted downwards when the rate of inflation exceeded its target, and vice versa.

Any systematic implementation of such a rule would have to operate in *real time*; that is, the target would have to be adjusted on the basis of currently available information, without the benefit of subsequently available data. In other words, feedback rules could rely only on one-sided estimates of potential output, precluding the use of some of the measures discussed above. This consideration is especially relevant to segmented trend measures like mid-expansion GNP. As noted earlier, extrapolating these series to provide current period estimates would usually fail to track contemporaneously changes in the growth of potential output.

A new, inflation-based measure of potential output

The alternative measure of potential real GNP described in Kuttner (1991) (see Box) uses a technique that differs significantly from those described above, relating potential output directly to the observed behavior of inflation. This method uses real GNP growth and inflation as gauges of the level of potential output, which itself is unobserved. Unlike existing measures, this technique explicitly recognizes the uncertainty involved in extracting a measure of potential output from the available data. An additional advantage of this technique is its ability to produce either one- or two-sided

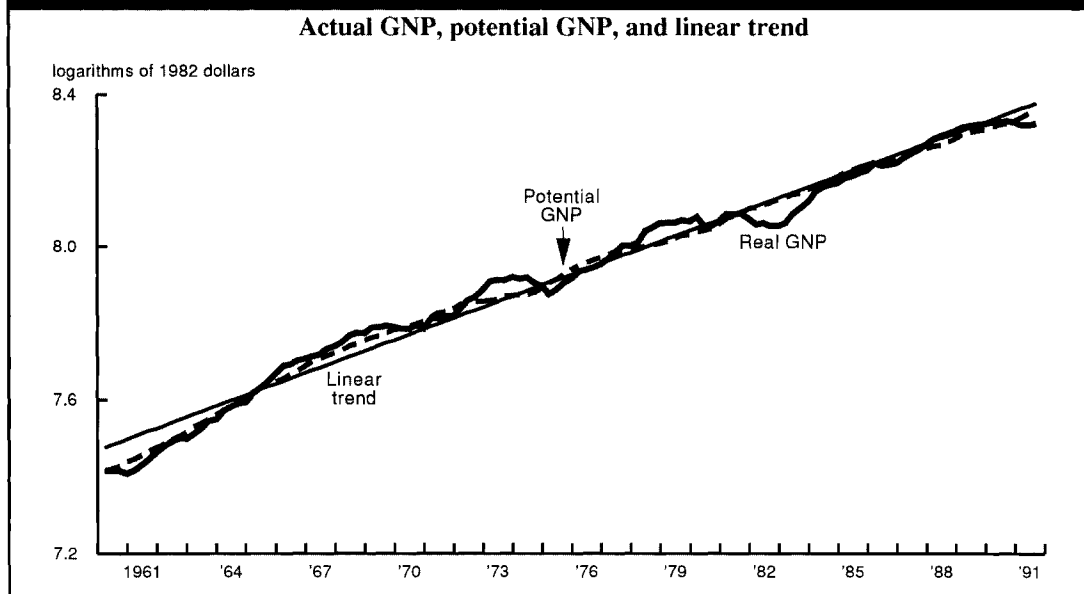
estimates; comparing them brings the distinction into sharp focus. An examination of the expansionary 1988-89 period illustrates the practical importance of this distinction.

This measure defines potential output in terms of two key attributes. First, it corresponds to a sustainable level of production; that is, a level consistent with stable future real growth rates. One way to capture this property is through an *error correction* equation for real and potential GNP. This equation describes the economy's real growth rate as a function of the discrepancy (the "error") between actual and potential GNP, and demand shocks. If output equals potential, the economy will grow at the same rate as potential, in the absence of demand shocks. When output exceeds potential, the economy tends to grow more slowly than potential, restoring equilibrium over time. Similarly, when the economy's real GNP is below potential, output tends to grow more rapidly. In this equation, demand shocks represent those factors that perturb the economy's adjustment process.

The second main feature of this measure is its connection to the inflation rate. As in the usual aggregate supply relation described earlier, potential output is defined as that level of output at which inflation shows no tendency to increase or decrease, holding other factors (money growth, for example) constant. When output exceeds potential, the inflation rate tends to rise, reflecting the upward slope of the aggregate supply curve. Because they both depend on the gap between actual output and unobserved potential output, real growth and inflation data can be used to estimate the size of the gap between the two.

Figure 2 plots the logarithm of potential GNP estimated using this technique, along with a linear trend and the logarithm of observed real GNP. Comparing potential output with the trend highlights the considerable time variation in potential output growth. From a relatively rapid growth rate in the early 1960s, potential output slows late in the decade and into the 1970s, reflecting the well known productivity slowdown of that period. Potential output growth increased once again in the early 1980s as oil prices stabilized, and the economy recovered from the 1981-82 recession.

While this method offers a convenient and appealing way to estimate potential output, it, like the traditional measures discussed earlier,

FIGURE 2

is an estimate of a somewhat imprecise entity. As such, it is important to emphasize that Figure 2 plots only the point estimate of potential output. Unlike the traditional measures, however, this new method models the error associated with estimating potential output, and provides an estimate of the magnitude of that error. The following section explores the consequences of this uncertainty for policy based on an uncertain estimate of potential output.

Uncertainty and macroeconomic policy

One of the most important practical problems facing policymakers is the uncertainty associated with contemporaneous measures of macroeconomic performance. Data revisions are evidence of the uncertainty that pervades even the most basic macroeconomic data. The advance estimate of GNP, for example, usually differs significantly from the preliminary and final estimates, released one and two months later. Even the final estimates are revised annually, as well as every five years during the benchmark revision process. Money stock statistics undergo similar revisions.¹¹

How should policy respond when economic signals are uncertain? To illustrate this problem with a specific example, consider the effects of data uncertainty. Suppose the Federal Reserve wishes to maintain nominal GNP growth at an annual rate of 7 percent. Suppose also that the advance national income data indicate nominal GNP growth of 8 percent. In

light of the likelihood of a subsequent downward revision to the data, should policy act now to reduce the growth rate of nominal GNP? Clearly, the proper reaction depends significantly on the amount of uncertainty: the less certain the estimate, the smaller the appropriate policy response.

In this example, the Federal Reserve's target is known with certainty, but the true state of the economy is not. The problem is compounded when the policy target itself is uncertain, as in the case of a potential output target.

One- versus two-sided uncertainty in potential output

One useful feature of the multiple-indicator model is that it can yield either one- or two-sided estimates of unobserved potential output. As described in the accompanying Box, the Kalman filter technique delivers the optimal estimate of potential output given the data available at the time. A complimentary algorithm—the Kalman smoother—uses data through the end of the sample to extract an estimate of potential output given both past and future data. At the same time, both the filter and the smoother also produce estimates of the statistical uncertainty associated with the estimate, referred to as filter uncertainty. An additional source of variance, the parameter uncertainty, comes from the estimation of the model's parameters.

Figure 3 displays the size of this uncertainty by plotting the two-sided estimate of potential output along with the 5th and 95th percentiles of its distribution, which represent the 90 percent confidence bounds, calculated using the technique proposed by Hamilton (1986). As reported on the last line of Table 1, the average two-sided standard error is approximately 1.4 percent (relative to the level of potential output), corresponding to a 90 percent confidence bound of over 2 percent. The contributions of the filter and parameter variance to the two-sided standard error, shown on the first two lines of the Table, show how the process of signal extraction and the imprecision of the parameter estimates contribute comparably to the uncertainty of the potential output estimate.

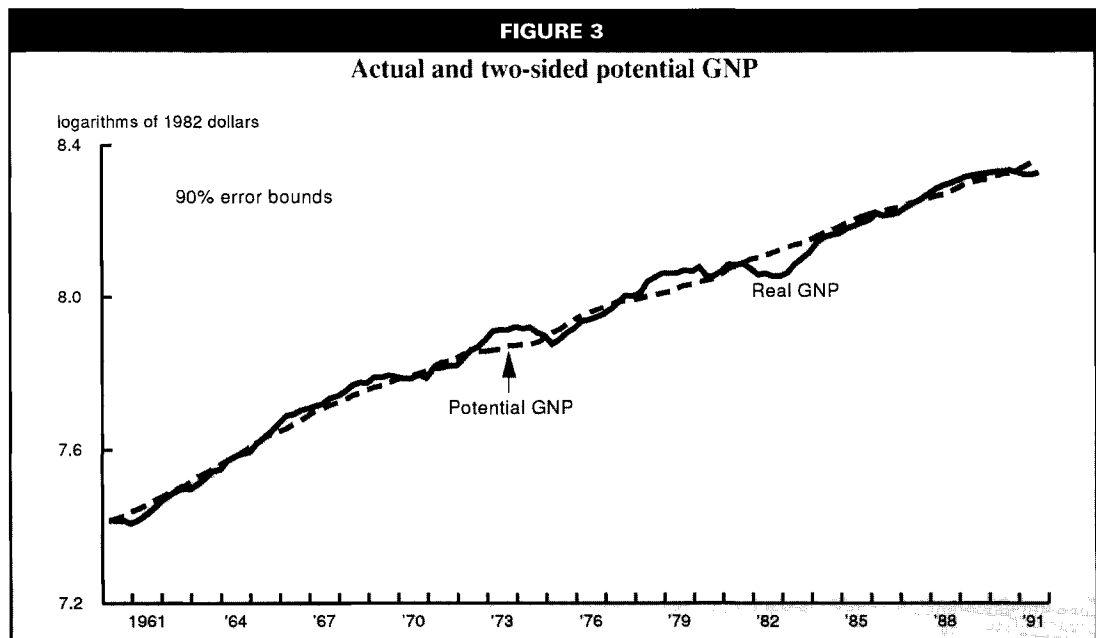
However, because the two-sided estimates rely on data unavailable to policymakers in real time, they understate the amount of uncertainty present in those estimates. A better measure of this uncertainty is that associated with the one-sided estimates. Comparing the two columns of Table 1 shows that with an average standard error of 1.62 percent, the one-sided estimates are less precise than the analogous two-sided series. While the two-sided estimates are more precise on average than the one-sided estimates, this is not true for the last quarter of the sample. Here, in the absence of data on future output growth and inflation, the two- and one-sided estimates, and their standard errors, are identical.

	Two-sided	One-sided
Filter variance	0.89	1.84
Parameter variance	0.99	0.81
Overall standard error	1.36%	1.62%

Why hindsight reduces uncertainty

Subsequent data improves the estimates' precision for two reasons. First, there is the physical lag. Certain indicators—notably inflation—react to GNP changes with a lag. The inflation equation of the potential output model incorporates this delay by relating the current change in the inflation rate to lagged values of the gap between output and potential. Thus, a widening of the output gap this quarter does not appear as a change in the inflation rate until the following quarter.

A second, more subtle reason for a lag comes from the process of signal extraction itself, in this case, the process of extracting an estimate of the unobserved level of potential output. This lag comes from the fact that the inflation and output data are noisy indicators of the output gap, subject to random movements which may not reflect a change in the level of potential GNP.



For instance, suppose we were to see an increase in the inflation rate from 5 percent to 6 percent over the span of one quarter. This additional inflation could be the sign of an overheating economy, as the added demand pressure led firms and workers to demand wage and price increases. On the other hand, the rise could be a fluke, the result of a statistical aberration, or special factors. If this were the case, interpreting the inflation as a symptom of a widening output gap would be a mistake.

There are two ways to distinguish mere blips from real demand pressure. First, one might look at the co-movement between inflation and output. If the inflation accompanied slackening output growth, the two indicators together would point to excess demand. Likewise, if the inflation continued over the course of several quarters, it would provide stronger evidence of an output gap. However, waiting around for more data to arrive takes time. And the less reliable the indicator—in time-series parlance, the larger the ratio of noise to signal—the stronger the inclination to wait for corroborating evidence to appear before taking action. In other words, signal extraction uncertainty can be characterized as another source of what Milton Friedman called the recognition lag, referring to the length of time it takes to recognize the appearance of a situation requiring a policy action.

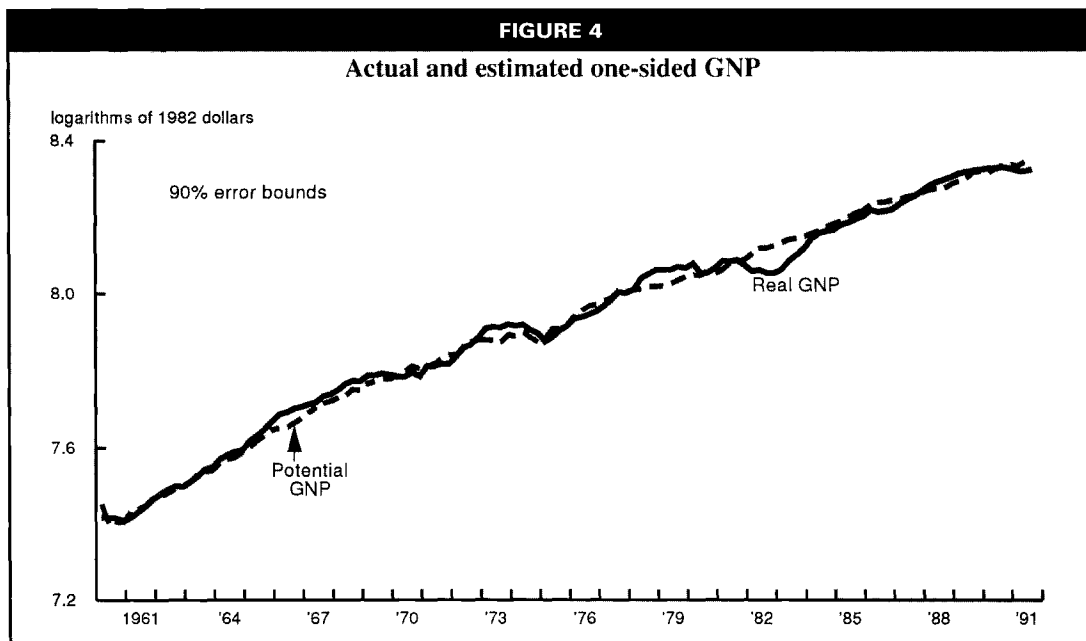
Discerning output gaps in real time

Except for the fact that the parameters of the model are estimated using data from the entire sample, the one-sided estimates roughly correspond to the estimates of potential output that would have been available to policymakers at the time. This raises the question of whether there are instances where the contemporaneous uncertainty surrounding the potential output goal is so large that appropriate policy corrections can be discerned only in retrospect.

The 1965-69, 1973-74, and 1978-79 expansions and the 1981-82 recession all represent statistically significant deviations of output from potential, as measured by the 90 percent bounds. However, the 1974-75 recession and the 1988-89 portion of the most recent expansion are ambiguous. Relative to the two-sided estimates in Figure 3, these two episodes are significant deviations from potential output. However, neither of these deviations is significant with respect to the one-sided 90 percent bounds in Figure 4, suggesting that at the time, distinguishing the appropriate course of monetary policy might have been difficult. The more recent episode is examined in greater detail below.

A closer look at the 1988-89 boom

One especially good illustration of the uncertainty problem is the small boom of 1988-89. After several years during which output fell

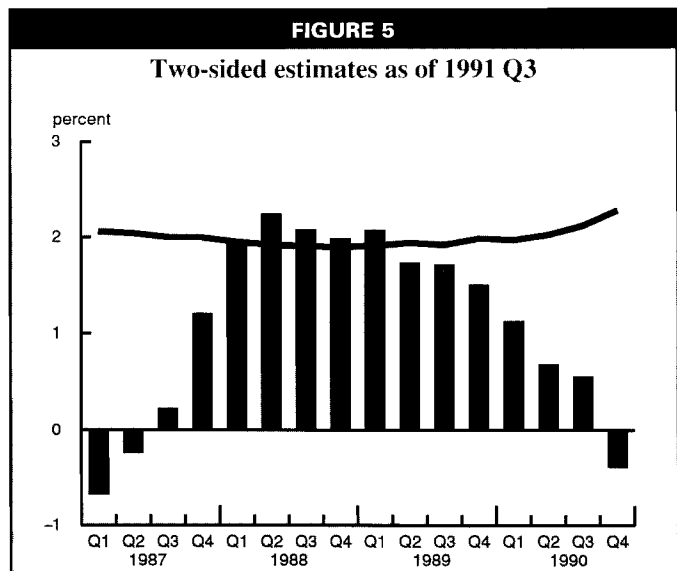


short of potential, the economy grew rapidly in 1987 and early 1988, achieving annualized real growth as high as 4.5 percent. Reacting to the economy's unforeseen strength, Federal Reserve policy gradually tightened throughout 1988, resulting in a rising federal funds rate. Using the term spread (the difference between the ten year Treasury bond yield and the federal funds rate) as a rough measure of monetary policy as suggested by Laurent (1988) and Bernanke and Blinder (1989), this change in policy corresponded to a decline in the term spread from +200 basis points in 1988:1 to -100 basis points in 1989:2. This section examines the

question of whether policymakers could have discerned this boom sooner and acted to offset it, given the data available at the time.

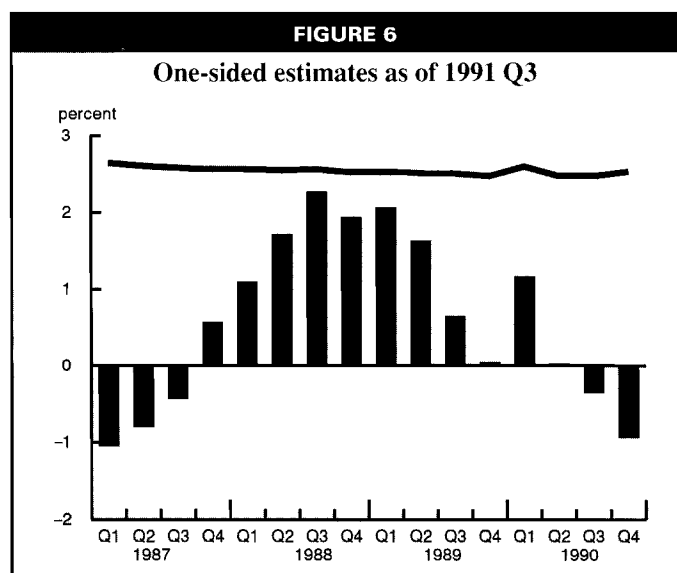
This question is explored in Figures 5-7. The bars in each graph represent the output gap—measured real GNP less estimated potential GNP—expressed in percentage terms. A positive output gap describes an overheated economy with increasing inflation pressure. Similarly, a negative output gap corresponds to subsiding inflation pressure. However, because they refer to the *level* of output relative to potential, negative output gaps do not necessarily correspond to recessions, which are typically defined in terms of the growth rate of real output. The solid line in each graph represents the upper 90 percent confidence bound discussed earlier. An output gap in excess of this bound says that the observed behavior of output and inflation is statistically quite unlikely to have come from an economy in which the output gap is zero.

Figure 5 shows the two-sided estimate of the output gap and its upper error bound. From the vantage point of 1991, it is apparent that the very rapid output growth of 1987-88 led real GNP to exceed potential by the first quarter of 1988, where the gap reaches 2.3 percent. Output continues to exceed the 90 percent confidence bound throughout the rest of 1988



and through the first quarter of 1989, at which point the gap gradually begins to fall. Meanwhile, although monetary policy was slowly tightening over this period, the term spread did not become negative—usually a sign of monetary restriction—until the first quarter of 1990. In retrospect, then, it appears that monetary policy should have tightened more rapidly in early 1988. Did the available data support such an action?

Figure 6 displays the analogous one-sided estimates of the output gap and the upper 90 percent confidence bound. As one-sided estimates, they are similar to those which would have been available at the time. However,



there is an important difference: while they do not explicitly use any post-dated data, the estimates are based on the *revised* GNP and M2 series available as of late 1991. Using these figures, the output gap never exceeds the upper error bound. The estimated output gap changes little between Figure 5 and 6. The main difference between the two is the size of the error bound: the two-sided bound is less than 2 percent, while the one-sided bound is nearly 3 percent. This discrepancy directly reflects the reduction in signal-extraction uncertainty that results from additional data. The policy implication of this comparison is striking: judged by the 90 percent error bounds, the case for faster monetary policy tightening was much less clear in 1988 than it is with hindsight.

Using the *unrevised* GNP data—those data actually available at the time—the evidence for quicker policy action becomes even weaker. Figure 7 shows the output gap based on one-sided estimates using the data available in the fourth quarter of 1989, which include the preliminary estimate of third quarter GNP. More importantly, these data also predate the 1990 annual revisions. Using these data, the one-sided error bounds are comparable to those in Figure 6. However, the output gap over the period is somewhat smaller, reaching a peak of only 1.9 percent, compared with 2.3 percent using the 1991 estimates. Behind this discrepancy is the fact that the initial figures from 1989 showed considerably stronger growth than the revised estimates. Because rapid output

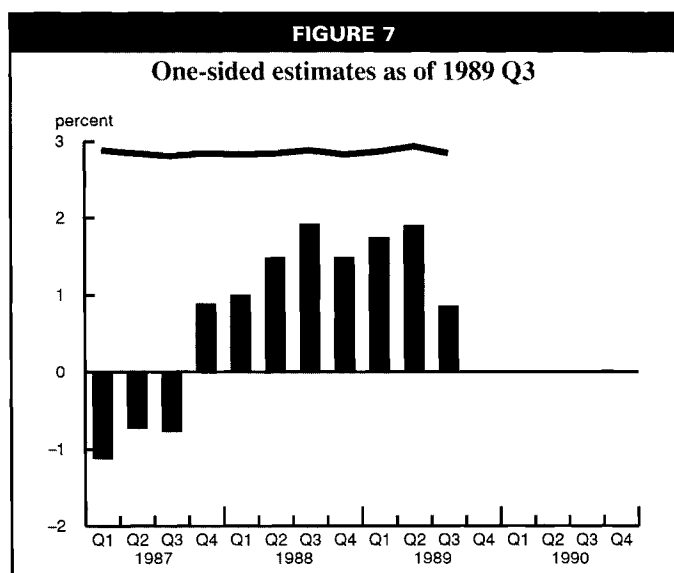
growth is normally associated with output being below potential, the model interprets faster-than-normal growth as one sign of a negative output gap. Thus the two sources of uncertainty—that associated with potential output and the error in estimating GNP itself—combined to distort the true state of the economy, complicating the policy decision.

Conclusions

To the extent that the Federal Reserve takes responsibility for dampening demand-induced fluctuations in the economy, it will—either explicitly or implicitly—base its policy on some appraisal of the economy’s level of potential output. This article has proposed a new technique for rigorously constructing such a measure, using inflation and real growth data to determine the level of GNP consistent with stable growth and constant inflation. This new potential output series successfully captures gradual changes in the economy’s underlying growth rate, without introducing the abrupt kinks that characterize series based on segmented trends. Furthermore, this new series is unique in the way it delivers a measure of the statistical uncertainty involved in constructing the series. As argued above, a measure of this uncertainty is essential for calibrating the response of monetary policy.

The explicit recognition of this uncertainty also highlights its consequences for real-time policymaking. Because the signal-extraction error associated with a given quarter’s estimate of potential output falls as more data become available, situations requiring policy action may not be recognizable until later on. This phenomenon limits the scope of monetary stabilization. Frequently, the best response to uncertainty is to adopt a wait and see attitude until more information becomes available. As demonstrated by the 1988-89 example, by that time it may be too late to respond effectively.

This conclusion is not limited to the case of potential output. So long as there is any uncertainty in policymakers’ assessment of economic conditions, monetary policy will never be able to



offset the undesirable effects of demand shocks. A less pessimistic restatement of the same conclusion is that reducing the error associated with measures of macroeconomic performance can improve the performance of policy, as more precise estimates enable policy to respond more quickly to changing economic conditions.

One way to improve the measurement of potential output is to incorporate other indicators of the gap between output and potential, such as the unemployment rate, or the rate of capacity utilization. Another way is to augment the model with measures of factor inputs: labor force and the capital stock. Both of these are promising directions for future research.

FOOTNOTES

¹For example, see Boschen and Mills (1990), Braun (1990), and Hallman, Porter, and Small (1989). Prominent in the academic literature is Blanchard and Quah (1989), who decompose output fluctuations into the distinct effects of supply and demand shocks. See also the references in Boschen and Mills (1990).

²The use of the term "full employment" in this context is somewhat misleading. Because supply shocks also create short term economic dislocation, full-employment potential need not correspond to a situation in which no resources go unused. One definition of potential output that takes the full-employment idea to an extreme is the DeLong and Summers (1988) measure. They argue that potential output should represent the *maximum* feasible level of output attainable during peacetime.

³Okun (1970), pp. 132-133.

⁴Eichenbaum (1991) provides a useful appraisal of the current state of RBC research. Further discussion of the implications for RBC theory for the measurement of potential output appears in Boschen and Mills (1990).

⁵Some recent RBC models do allow demand shocks to affect real variables: Cooley and Hansen (1989) and Christiano and Eichenbaum (1990) are examples.

⁶To be precise, competitive equilibria are Pareto efficient, meaning no individual in the economy could be made better off without making someone else worse off. This is a statement of the well known First Welfare Theorem of general equilibrium economics.

⁷A recent exposition of the traditional approach to macroeconomic fluctuations appears in Blanchard (1989).

⁸DeLeeuw and Holloway (1983) describe the construction and use of the BEA's mid-expansion and high-employment measures.

⁹Papers discussing the CEA's methodology include Perry (1977) and Clark (1979).

¹⁰This series gained prominence as the potential GNP series used in Hallman, Porter, and Small's (1989) definition of P^* . Aside from the choice of breakpoints, *a priori* judgment is also implicit in the choice of the four w_i distributed lag weights in Braun's Equation C.1.

¹¹See Strongin (1986).

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