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Estimating the Output Gap in Real Time

by Anton Cheremukhin

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Estimating the Output Gap in Real Time

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Abstract

I propose a novel method of estimating the potential level of U.S. GDP in real time. The proposed wage-based measure of economic potential remains virtually unchanged when new data are released. The distance between current and potential output — the output gap — satisfies Okun's law and outperforms many other measures of slack in forecasting inflation. Thus, I provide a robust statistical tool useful for understanding current economic conditions and guiding policymaking.

JEL codes: C18,C80,E01
Keywords: Output gap; economic potential; estimation.

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Was the U.S. economy on the path to recovery over the past four years of steady growth? How many more years of growth will it take to reach full potential? These questions are the topic of intense debate because of substantial uncertainty surrounding real-time estimates of the output gap, a measure of the distance between current output and the economy's productive potential.

There are at least three reasons for the uncertainty. First, the existence of a wide variety of models implies a variety of estimates of potential GDP. Second, model parameters are updated over time based on new data releases, which leads to reassessment of output gap estimates in earlier periods. Finally, data themselves are revised over time. As a consequence, oftentimes, it takes a decade to obtain a reasonably precise estimate of the output gap.

In this paper, I propose a novel method of producing a real-time estimate of the output gap that minimizes the joint uncertainty coming from the choice of model and from parameter updates. I choose a model based on two robust economic relationships: the long-run stability of the labor share and the strong comovement between investment and GDP. My choice of model minimizes both the number of re-estimated parameters and the uncertainty associated with estimates of each parameter. The third source of uncertainty, revisions to previously published data, plays a lesser role (see Orphanides and van Norden 2002). Therefore, my estimate eliminates the biggest source of error. To illustrate the stability of the results, I show that my estimate of the output gap remains virtually unchanged when new data are released.

In addition to statistical precision, to be useful for guiding policy decisions, a measure of the output gap needs to satisfy basic economic intuition. First, the Federal Reserve's goal of maintaining full employment should correspond to an estimate of the output gap of zero. Second, economic theory dictates that a positive output gap is associated with increased price pressures as a consequence of overheating in the economy. Therefore, an estimate of the output gap should have predictive power in forecasting inflation. I show that my real-time estimate of the output gap satisfies both of these criteria. It satisfies Okun's law and outperforms many other measures of economic slack in forecasting inflation.

The paper proceeds as follows. In Section 1, I present an overview of models of economic potential. In Section 2, I describe my methodology of constructing the output gap. In Section 3, I explore the business cycle properties of my wage-based estimate of the output gap and show that it satisfies the basic economic requirements. In Section 4, I compare the properties of this estimate of the output gap with outcomes of other statistical procedures. I conclude with words of caution.

1. MODELS OF TREND

The literature[1] describes three approaches to modeling trend: the aggregate approach, the growth-accounting approach and the DSGE approach. These three groups of models differ by the modeling assumptions that are used to identify potential output. Here I discuss the role that these modeling assumptions play in shaping up the advantages and drawbacks of each approach.

The *aggregate* approach uses aggregate variables, and relationships between them, to derive measures of potential output. This approach can be split into two branches by the criterion of whether it uses a univariate or multivariate statistical model. Models based on the *univariate* approach use statistical methods to identify the permanent component of changes in output and assume that the permanent component is a reasonable measure of potential output. Models in this vein started with the work of Beveridge and Nelson (1981) and Clark (1987). The Hodrick-Prescott filter (1997), a statistical procedure commonly used in the macroeconomic literature to identify the cyclical and trend component of any macroeconomic time-series, is another example of the univariate aggregate approach. This filtering technique has been extended by Christiano and Fitzgerald (2003) to band-pass a prespecified range of frequencies.

The obvious advantage of this approach is due to its simplicity and transparency: The assumptions are clear, and the methodology is easy to implement. The main disadvantage, however, is that the estimates of potential output turn out to be sensitive to the statistical assumptions regarding the properties of the permanent and cyclical components of output. Given that economic theory provides little guidance on how to discipline these assumptions, model parameters have to be constantly re-evaluated when new data are released. Therefore, the main disadvantage of the univariate approach stems from the fact that the assumptions it is built upon are not a robust property of the data. Another problem with the univariate approach is that it is not clear why an outcome of a univariate procedure should be helpful for predicting inflation. Thus, this approach does not necessarily provide a measure consistent with the theory through the lens of which it will be analyzed.

One potential fix to this problem could come from assumptions rooted in economic theory replacing the statistical assumptions. Among the variety of possibilities that this thought provokes, the most common

[1] In this overview, I borrow the classification introduced by Mishkin (2007).

approach is to eliminate both disadvantages of the univariate approach in one blow. This can be done by invoking the relationship between inflation and the output gap: the Phillips curve. The “natural rate” version of the Phillips curve predicts that any attempt to lower unemployment below its natural rate will result in higher inflation. Taking into account Okun’s law — the relationship between changes in unemployment and output, named after Okun (1962) — one can exploit the tendency of inflation to move up or down depending on the difference between actual and potential output.

This approach is called the *multivariate* aggregate approach because it brings in several aggregate variables and exploits their comovement. Prominent examples of this approach include Kuttner (1994) and Laubach and Williams (2003). The main advantage of multivariate models is that economic assumptions involved in the estimation make the level of potential output easier to interpret intuitively and, thus, more useful for guiding policy decisions.

However, replacing statistical assumptions by economic assumptions makes the estimates less robust. The reason for this is that the economic relationships that are chosen to infer the level of potential output are unstable. In particular, there is considerable disagreement on the precise specification of the Phillips curve and substantial uncertainty regarding its slope. A measure of potential output based on a multivariate model that re-estimates the Phillips curve relationship with every new data release naturally inherits the uncertainty surrounding the parameters of the Phillips curve. In fact, the findings of Orphanides and van Norden (2002) indicate that the sensitivity to new data of output gap measures coming from multivariate models based on the Phillips curve is larger than the sensitivity of univariate measures of the output gap, such as the HP-filter.

The *growth-accounting* approach uses a decomposition of output into a weighted average of factors of production: labor services, capital services, and multifactor productivity. If the contribution of each factor is known and the potential for growth in each factor of production can be inferred from microeconomic data, computing the potential level of output is straightforward. This is the approach implemented by the Congressional Budget Office (CBO).

The main advantage of the growth-accounting approach is that it focuses on factors that drive growth rather than on historical relationships. The approach takes advantage of microeconomic relationships that explain structural changes in productivity and population dynamics. These relationships are used to project potential output in future periods. Hence, estimates of potential output are available many years in advance, and the implied output gap is transparent: The contribution of each factor of production to the output gap is available.

The main weakness of the approach comes from the fact that the microdata used for projections are not updated regularly. Consequently, updates to the estimate of potential GDP are also infrequent. However, when such an update comes out, the revision to estimated potential GDP typically is substantial. This implies that the growth-accounting estimate of potential GDP is not suitable for real-time analysis. In addition, the instability of estimates suggests that the relationships between microeconomic variables exploited by this approach may be unstable. However, this may compound other problems, such as the difficulty in acquiring microeconomic data, its inaccuracy, as well as the judgment calls involved in making the projections.

The *dynamic stochastic general equilibrium (DSGE)* approach provides an alternative view on the definition of the output gap. Potential output is defined by this approach as the level of output that could be attained under flexible nominal wages and prices. This approach takes the stand that nominal rigidities are the only source of inefficiency in the economy that should be targeted by monetary policy. Therefore, the component of output fluctuations that is not due to nominal rigidities is not considered to be part of the output gap by the DSGE approach. For a recent application of the DSGE approach, see Kiley (2013).

The advantage of the DSGE approach is that policy actions can focus on removing the inefficiencies originating from nominal rigidities in prices and wages. The disadvantages are related to the fact that the development of DSGE models is in its infancy, so existing DSGE models fit the data poorly. Consequently, the output gap based on a DSGE model is sensitive to seemingly innocuous modeling assumptions. For instance, potential output can fluctuate with the business cycle or remain stable, depending on how the driving forces of the business cycle are identified. This is not surprising given that the original real business cycle model, which views business cycles mainly as an efficient response to shocks, can explain a large share of business cycle movements. Moreover, there may be other sources of inefficiency, such as real rigidities and inefficiencies originating from the fiscal theory of the price level, that monetary policy is capable of correcting. In this case, the misspecification of the model adds uncertainty to any measure of the output gap produced using the DSGE approach.

2. METHODOLOGY

My modeling assumptions represent a hybrid of the growth-accounting approach and the multivariate aggregate approach. In particular, the procedure I propose proceeds in three logical steps. The first two steps build on the growth-accounting approach, while the third step uses comovement of variables to correct the errors introduced by the first two steps of the procedure. In this section, I first describe the economic intuition behind all three steps of my algorithm. Then, I compare the proposed methodology to existing methods and discuss its advantages and drawbacks. Finally, I describe my U.S. data sources.

1. In the first step, I construct a measure of trend in nominal labor income by multiplying the labor force by compensation per hour. The idea behind this measure originates from Keynes (1936), who in Chapter 4 of his *General Theory* proposed to count all nominal economic quantities in units of hourly wages. My rationale for reviving this old concept (see also the work of Farmer 2008 and Plotnikov 2012) is that hourly wages capture two factors that contribute to the growth of potential output: productivity and the price level. Thus, the product of hourly wages and the labor force, in addition to growth in productivity and prices, captures the growth in the number of people that could potentially contribute to production. The next two equations summarize the parallel between actual labor income and potential labor income. They are reminiscent of the growth-accounting approach to measuring the output gap described in the previous section.

$$\text{Labor Income} = \text{Employment} * \text{Hours per worker} * \text{Compensation per hour} \tag{1}$$

$$\text{Potential Labor Income} = \text{Labor Force} * \text{Constant Conversion Factor} * \text{Compensation per hour} \tag{2}$$

2. In the second step, I use the long-run stability of the ratio of labor income to GDP, a well-documented and empirically robust economic relationship,[2] commonly satisfied by economic theories as a consequence of an assumption of a Cobb-Douglas aggregate production function. By assuming that the share of labor income to GDP remains constant in the long run, I convert my measure of trend in nominal labor income into a measure of trend in nominal GDP.

$$\text{Prelim. Output Gap} = \text{Nominal GDP} \;/\; (\text{Nominal Compensation} \;/\; \text{Hours}) \;/\; \text{Labor Force} \tag{3}$$

The first two steps are enough to construct preliminary measures of trend output and the output gap. As shown in equation (3), the *preliminary output gap* is simply the normalized value of nominal GDP divided by the labor force and by compensation per hour.

Although this measure is stationary,[3] it may still contain a nontrivial residual noise component because of short- and medium-term fluctuations in the labor share, hours per worker, and the labor force participation rate. These fluctuations may introduce a bias into the estimate of the output gap. That is why I refer to it as a preliminary estimate. The goal of the third step of my procedure is to alleviate this bias. To better identify the true output gap and eliminate the noise component, I introduce a third step.

3. In the third step, I rely on the statistical properties of the relationship between GDP and investment. Three especially robust properties are well documented: a) The ratio of investment to GDP is stable in the long run;[4] b) Growth rates of investment and GDP are highly correlated at business-cycle frequencies (+0.85); c) Investment is three to five times more volatile than GDP.

$$\text{Prelim. Investment Gap} = \text{Nominal Investment} \;/\; (\text{Nominal Compensation} \;/\; \text{Hours}) \;/\; \text{Labor Force} \tag{4}$$

Property (a) allows me to construct the investment gap in the same way as the output gap — by using potential labor income as a measure of potential. The preliminary measures of the output and

[2] Recently, there has been some controversy regarding the long-run stability of the labor share. The series for the ratio of compensation to GDP in the U.S. may have been on a downward trend since 2000. In Section 4, I test the robustness of my findings to the assumption of long-run stability of the labor share and quantify the sensitivity of my estimates to this assumption.

[3] All available unit root tests indicate that the preliminary output gap is stationary at a 1-2 percent confidence level.

[4] All available unit root tests indicate that the investment's share in U.S. GDP is stationary at a 1 percent confidence level.

investment gaps, constructed in this way, are stationary and highly correlated, consistent with property (b). In agreement with property (c), the investment gap is significantly more volatile than the output gap. Nevertheless, by construction, the noise component in investment introduced by the assumptions of steps 1 and 2 is the same as in output. Therefore, the noise to signal ratio of the investment gap is much smaller than that of the output gap. This statistical property makes the investment gap especially useful for extracting the cyclical component of the output gap.

In the third step, I extract the common component of the preliminary investment and output gaps[5] using equations (5) through (7), where Y_t denotes the common noise component, X_t denotes the true output gap, and u_t and v_t are i.i.d. measurement errors. I assume that the contribution of the common component to output, X_t, represents the final measure of the output gap. The preliminary output gap and the component $Y_t + u_t$, eliminated by the third step, are shown in Figure 1. A comparison of the final measure of the output gap to the CBO's estimate and to the estimate obtained using an HP-filter is shown in Figure 2. The measure of trend GDP is then computed by subtracting the final output gap X_t from nominal or real output, as shown in Figure 3.

$$\text{Prelim. Output Gap} = Y_t + X_t + u_t, \tag{5}$$

$$\text{Prelim. Investment Gap } = Y_t + AX_t + v_t, \tag{6}$$

$$\text{Final Output Gap } = X_t \tag{7}$$

Overview. The first two steps of the procedure bring in elements of the growth-accounting approach. In the first step, I focus on the contribution of labor inputs to output. I replace the actual level of hours by its potential level, represented by the product of the potential number of workers, the labor force, and a constant factor that converts workers to hours. The assumption that compensation per hour reflects the improvements in productivity leads to a measure of the potential labor input contribution.

The second step, by noting the stability of the labor share over long horizons, implicitly assumes that the behavior of other factors contributing to potential output is proportional to the behavior of the potential labor input contribution. Thus, a weighted sum of all contributions must also be proportional to the potential labor input contribution.

The third step of the procedure corrects the potential errors introduced by assumptions made in the first two steps by applying the multivariate aggregate approach. The third step builds on the statistical properties of investment and GDP to extract their common component. As I show in sections 3 and 4, it eliminates a large fraction of the noise introduced by inaccuracies in the relationships used in the first two steps.

My measure of the output gap has two convenient properties. First, as I show later, past estimates of the output gap are virtually immune to new data releases. Due to the fact that the empirical regularities used in the algorithm, the long-run stability of the labor share and the comovement between investment and GDP, are particularly empirically robust, new data releases do not lead to noticeable revisions of the estimates of parameters. Consequently, the initial estimate of the output gap in period t remains virtually unchanged when data for later periods, $t + \Delta$, become available.

Second, my measure of the output gap can be computed in real time, namely, at the same point in time when an estimate of quarterly GDP becomes available. This property is due to the fact that all the data used in the estimation are released in a timely manner on a quarterly basis by the national statistical agencies. Next, I list the sources of data that I use.

As a proxy for compensation per hour, I use the ratio of total nominal compensation of employees, reported by the Bureau of Economic Analysis (BEA) on a quarterly basis, to aggregate hours of wage and salary workers on nonfarm payrolls, reported quarterly by the Bureau of Labor Statistics (BLS). The labor force is a quarterly average of monthly values reported in the survey of households conducted by the BLS. Data on nominal and real GDP, as well as nominal investment, are reported quarterly by the BEA.

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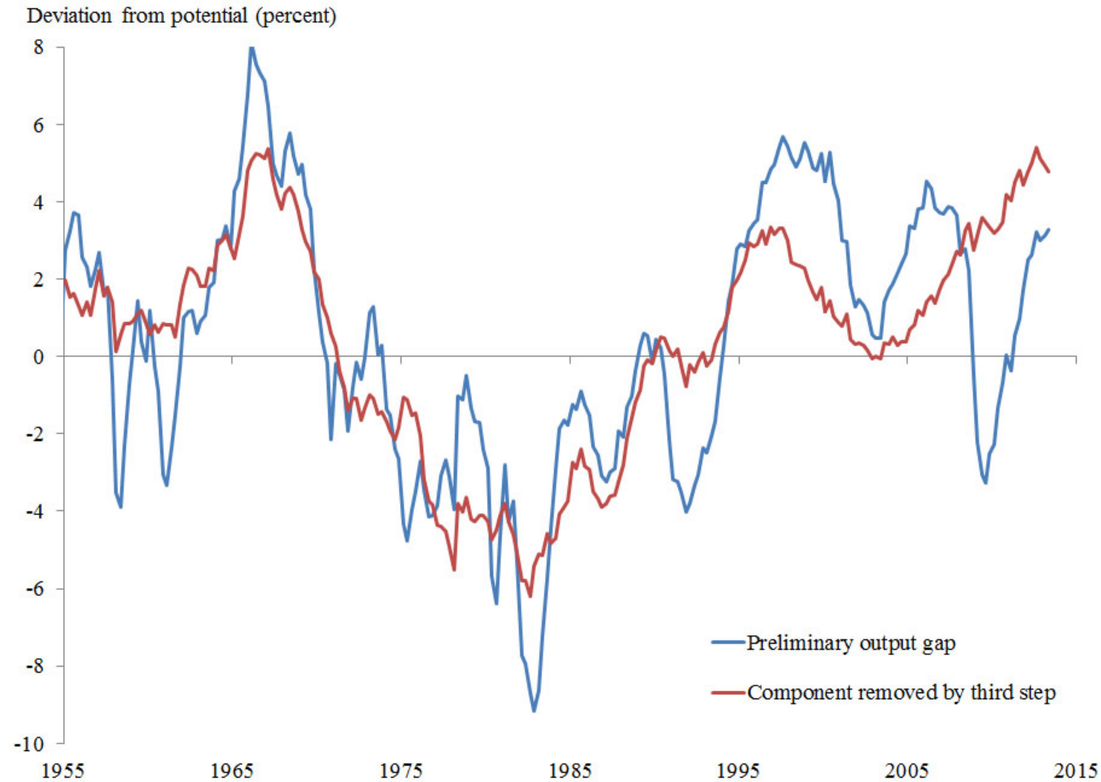
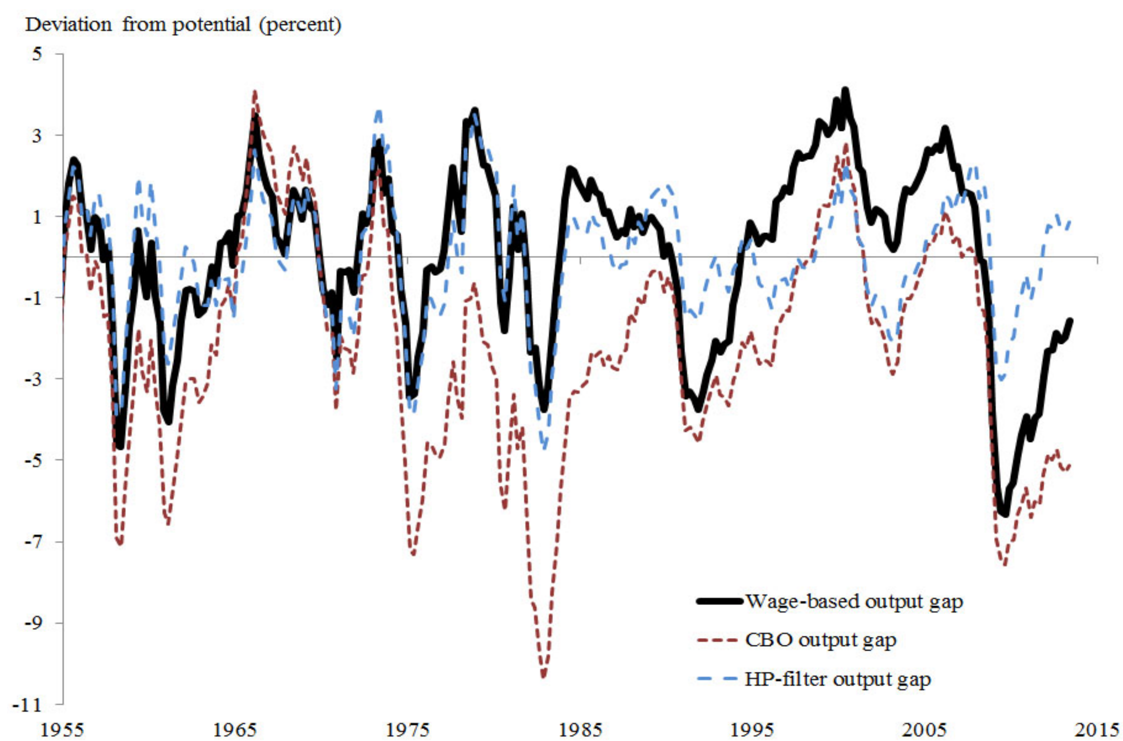
[5] A variety of procedures to extract the common component, such as factor analysis, a Kalman filter, or simple linear regression methods, all give identical results.

Figure 1: Effect of the Third Step on the Measure of Output Gap



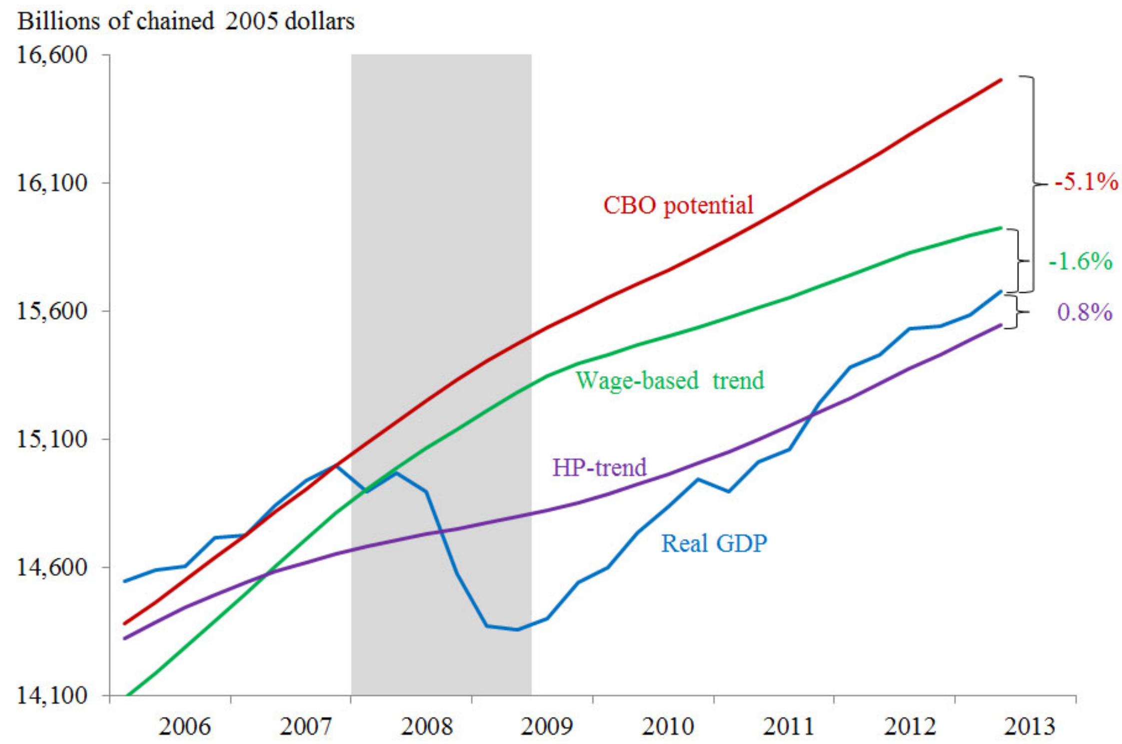
SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, author's calculations.

Figure 2: Measures of Output GDP



SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, Congressional Budget Office, author's calculations.

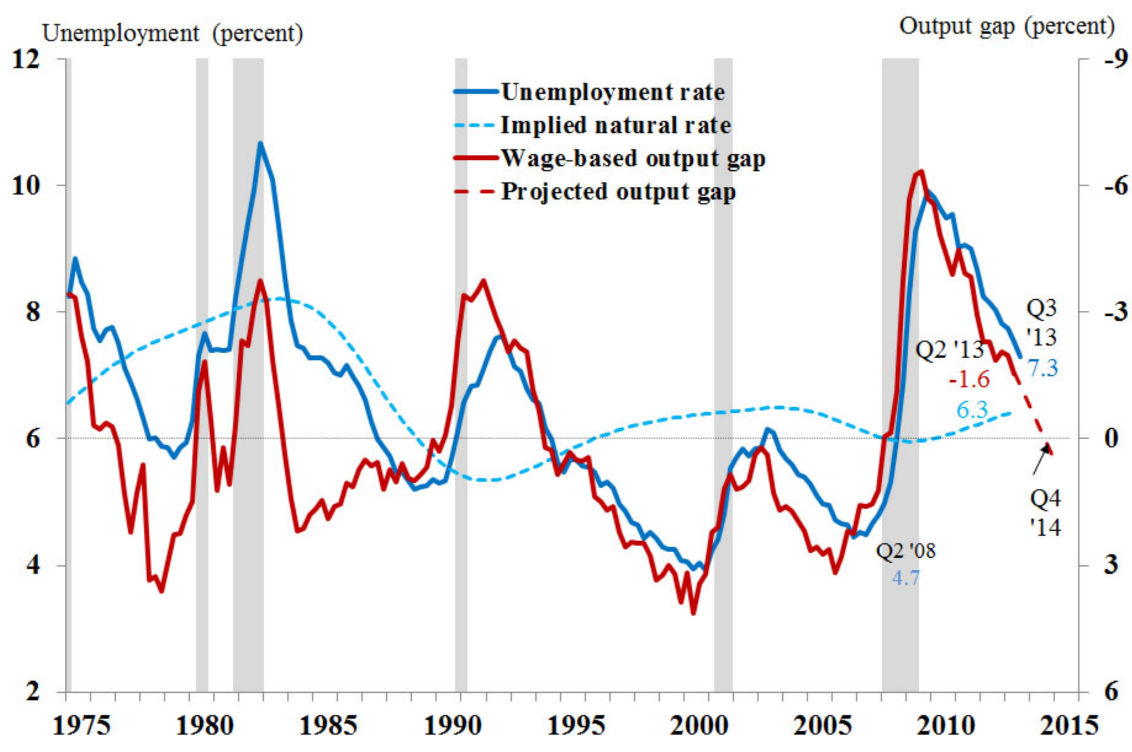
Figure 3: Measures of Trend in Real GDP



NOTE: Shaded areas indicate recessions.

SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, Congressional Budget Office, author's calculations.

Figure 4: Output Gap Satisfies Okun's Law



NOTE: Shaded areas indicate recessions.

SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, author's calculations.

3. RESULTS

Figure 3 shows the behavior of my wage-based measure of economic potential over the past decade. For comparison, I plot in the same figure the Hodrick-Prescott trend and the CBO's estimate of the potential level of GDP, which represent, respectively, the aggregate and the growth-accounting approaches discussed in the previous section. Although the aggregate approach has inspired a multitude of estimates of economic potential, here I use the method designed by Hodrick and Prescott (1997). As documented by Orphanides and van Norden (2002), the HP-trend remains among the least sensitive to new data releases of all methods in this class.

The three measures of potential shown in Figure 3 tell starkly different stories about the ongoing recovery process from the Great Recession. According to the CBO's measure, in the past four years the pace of growth has been narrowly sufficient to keep the gap from expanding further, but far short of the pace necessary for catching up with potential.[6] However, by using the HP-trend one may arrive at the opposite conclusion, namely, that the output gap is already in positive territory and a new downturn may happen sometime soon. My wage-based measure of potential implies that the recovery to potential is proceeding at a normal pace and the U.S. economy should be able to cover this distance within the next year and a half.

Okun's Law. Figure 4 compares the (rescaled inverse of the) output gap with the behavior of unemployment. It demonstrates that my measure of the output gap is consistent with Okun's law, which predicts that every 1 percent reduction in the unemployment rate translates into an increase in the output gap of 1.5-2 percent.

Notable deviations of the level of unemployment from Okun's law in the late 1970s and early 1980s are often attributed to an increase in the so-called "natural rate" of unemployment. To check this intuition, I plot the implied natural rate of unemployment on Figure 4. To estimate its level, I take a moving average of the difference between the output gap and the unemployment rate. Figure 4 demonstrates that not only does my measure of output gap satisfy Okun's law. In addition, the implied natural rate is consistent with commonly held beliefs about its behavior. Namely, it increased above 6 percent in the 1970s and reverted back by the late 1980s. The implied natural rate increased slightly during the recovery from the most recent recession by approximately 0.4 percent.

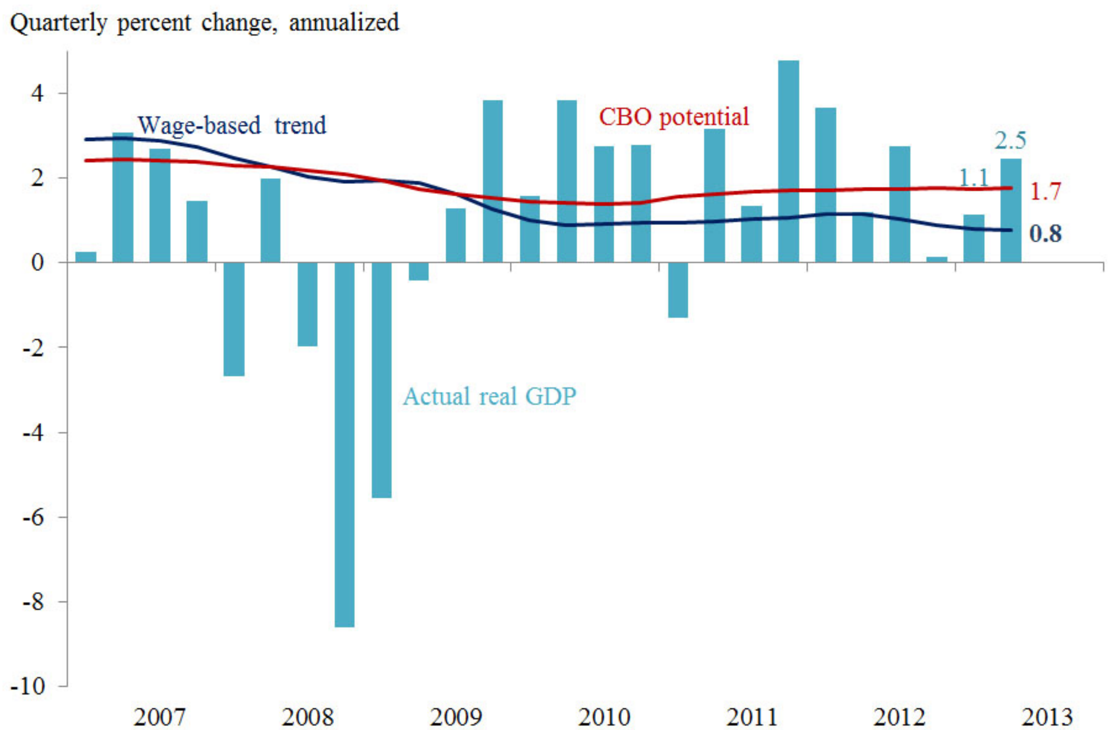
Recovery Speed. In Figure 5, I compare the pace of expansion of my wage-based measure of potential output with that computed by the CBO and the path of growth in real GDP. The wage-based measure indicates a substantial slowdown in the pace of expansion of the economic potential since 2000. The way it is constructed naturally decomposes growth in potential real output into two factors: growth of the labor force and improvements in efficiency.

As shown in Figure 6, both slower growth in economic efficiency and a slowdown in the growth rate of the labor force contribute to the slowdown in potential growth. The reduction in the labor force participation rate started more than a decade ago, is currently accelerating largely due to early retirement of baby boomers (see Hornstein and Rhodes 2013), and is expected to last for another two decades due to demographic factors, as shown in Szafran (2002) and many others. The slight reduction in the pace of improvement of economic efficiency may reflect the difficulties this adjustment process imposes on the aging labor force. A similar adjustment process was under way in the late 1970s and early 1980s when the entrance of baby boomers into the labor force and increased participation of women led to a reduction in average economic efficiency, as illustrated in Figure 4.

The gradual slowdown in trend implies that the speed of recovery from the last recession, that is, the speed of growth net of trend, has been 1.3 percent per year — not stellar, but much higher than the speed one could infer from the estimates of the CBO. As shown in Table 1, this pace is similar to many past recessions, in fact not far behind compared with the average pace of recovery from all seven recessions in the sample.

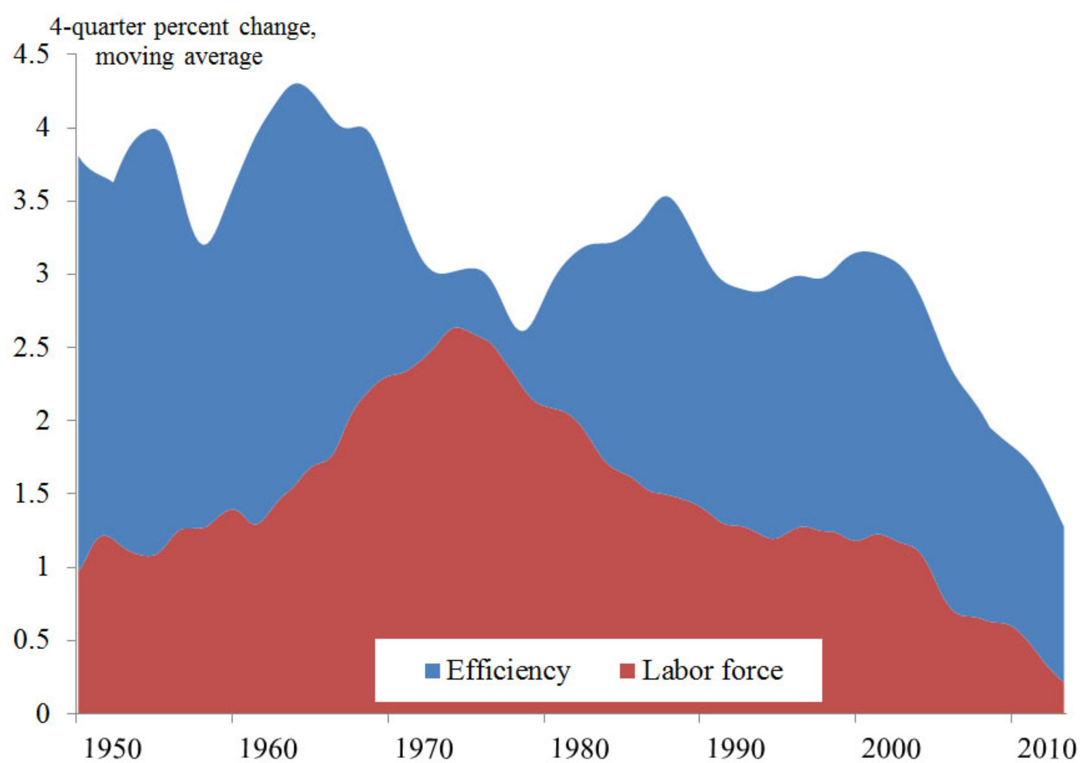
[6] The difference of my measure with the CBO's estimate has two main sources. First, the CBO assumes a slower decline in labor force participation than has been observed. Second, the CBO assumes that this factor affects only the contribution of labor to GDP growth, while my estimate (due to step 2) assumes that it affects all components of GDP equally.

Figure 5: Real GDP Growth Above Trend



SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, Congressional Budget Office, author's calculations.

Figure 6: Decomposition of Growth in Potential Real GDP



SOURCE: Author's calculations.

Table 1: The Speed of Recovery in a Historical Perspective

Recovery Start	Recovery Until	Average recovery rate
1954:Q2	1956:Q4	1.61
1961:Q1	1963:Q3	1.53
1970:Q4	1973:Q2	2.12
1975:Q1	1977:Q3	2.25
1982:Q4	1985:Q2	2.08
1991:Q4	1994:Q2	1.59
2003:Q1	2005:Q3	1.01
Average of 7 recoveries		1.74
2009:Q3	2013:Q2	1.28

SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, author's calculations.

Inflation Pressures. A desirable feature of a good measure of the output gap is its ability to forecast inflation pressures. To assess whether my wage-based measure is useful for forecasting inflation, I follow the methodology of Koenig and Atkinson (2012) and use the twelve-month Trimmed Mean PCE inflation rate as a measure of inflation because it is relatively less volatile compared with headline inflation and gives a good proxy of underlying current and future inflation pressures. By splitting the period of available data since 1985 in two parts at the turn of the century, I delineate the first period for estimating a forecasting relationship and the second period for assessing out-of-sample forecast performance.

I estimate a relationship between the current inflation rate, π_t, net of the Survey of Professional Forecasters (SPF) long-forward inflation expectations, π_t^{LF}, and a four-quarter lag of inflation. Key explanatory variables include the level of the output gap, x_t, and the four-quarter change in the output gap:

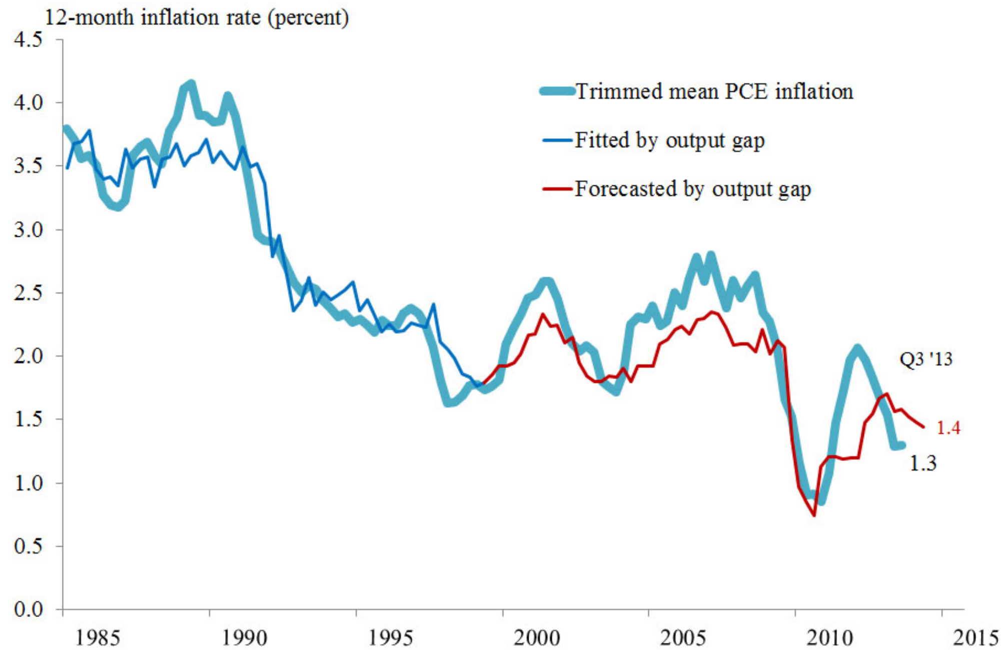
$$\pi_t - \pi_t^{LF} = \alpha + \beta \left(\pi_{t-4} - \pi_{t-4}^{LF}\right) + \gamma x_{t-4} + \delta \left(x_{t-4} - x_{t-8}\right) \tag{8}$$

The results of the forecasting exercise using various measures of the output gap are presented in Table 2. These results show that (the one-quarter change in) the wage-based measure performs at least as well as using (the three-quarter change in) the unemployment rate. It does much better than most other commonly used measures of the output gap, both in-sample and out-of-sample. A hybrid model, which combines the level of a wage-based output gap and a thre-quarter change in unemployment, cannot improve upon the wage-based measure although it combines the most useful information from both series. Figure 7 illustrates the out-of-sample fit of forecasts of inflation produced using the wage-based measure of the output gap.

However, note that inflation forecasting is far from being the primary objective behind the development of my measure of the output gap. Thus, this forecasting exercise serves as a simple check of consistency with economic intuition, and the results of the exercise are purely suggestive. There remain a large number of caveats related to the choice of time period, measure of inflation, additional explanatory variables, and the non-real-time nature of the forecast.

In this section, I have demonstrated that my measure of the output gap satisfies two most commonly held economic beliefs regarding the business-cycle properties of the output gap. First, the wage-based measure is consistent with Okun's law, both in differences and in levels. Second, the wage-based measure is consistent with the "natural rate" version of the Phillips curve helpful in forecasting price pressures. These are two necessary economic conditions that turn a measure into a useful tool for guiding policymaking. More important, in the next section, I discuss the statistical properties of my measure that make it convenient from a practical standpoint.

Figure 7: Output Gap Useful for Year-Ahead Inflation Forecasts



SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, Federal Reserve Bank of Dallas, author's calculations.

Table 2: Forecasting Performance of Different Measures of the Output Gap

Gap measure	Standard error Fitted	Forecast
None	0.293	0.479
CBO potential	0.246	0.445
Hodrick-Prescott filter	0.251	0.418
Unemployment level	0.243	0.386
Wage-based measure	0.246	0.328
Hybrid model	0.242	0.350

SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, Congressional Budget Office, Federal Reserve Bank of Dallas, author's calculations.

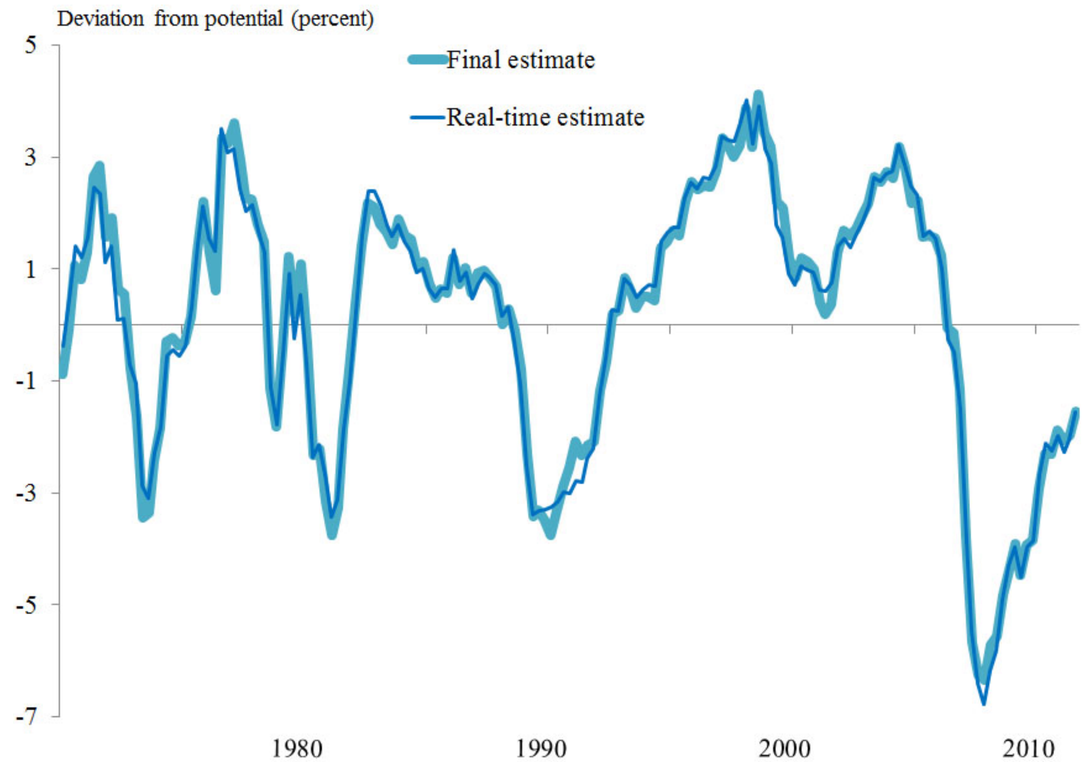
4. STATISTICAL PROPERTIES

Orphanides and van Norden (2002) identify updates to parameter estimates due to new data releases as the most serious problem underlying the unreliability of end-of-sample estimates of the output gap for existing measures of the output gap. They argue that this property makes the majority of existing measures unsuitable for real-time policy analysis. In this section, I demonstrate that, unlike other measures, my measure does not "wiggle its tail."

To demonstrate that, I compute the estimates of the output gap that my method would have produced based on data available at earlier points in time. I compare the real-time estimates of the output gap with "final" estimates, that is, estimates computed as of 2013, in Figure 8. Figure 8 demonstrates that there is virtually no difference between the final estimates and the real-time estimates of the output gap.

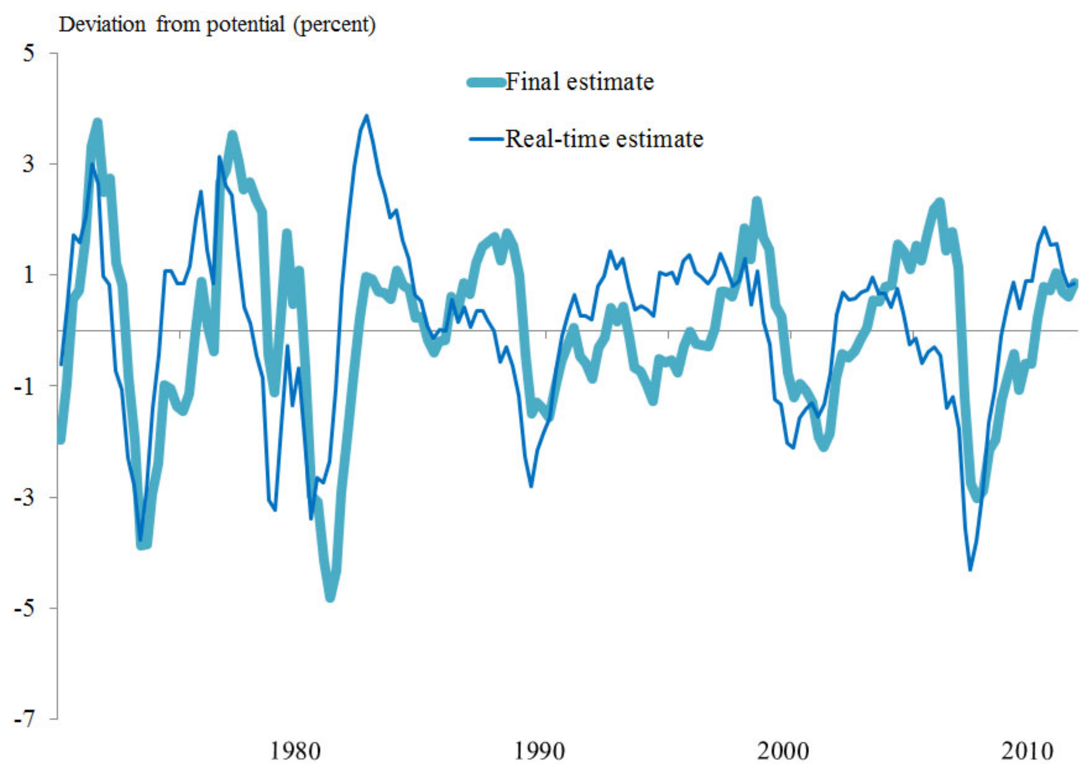
Figure 9 shows a comparison of real-time and final estimates of the output gap using the Hodrick-Prescott filter. The stark contrast between the two figures demonstrates that my real-time estimates of the output gap are an order of magnitude more robust to new data releases than those produced by the HP-filter or the band-pass filter. As mentioned earlier, Orphanides and van Norden's estimates imply that among the variety of aggregate methods, based either on the univariate or the multivariate approach, the HP-filter has nearly the lowest root mean square error (RMSE) due to new data releases. This implies that my method outperforms by an order of magnitude all of the methods in terms of real-time robustness.

Figure 8: Stability of Wage-Based Measure of the Output Gap



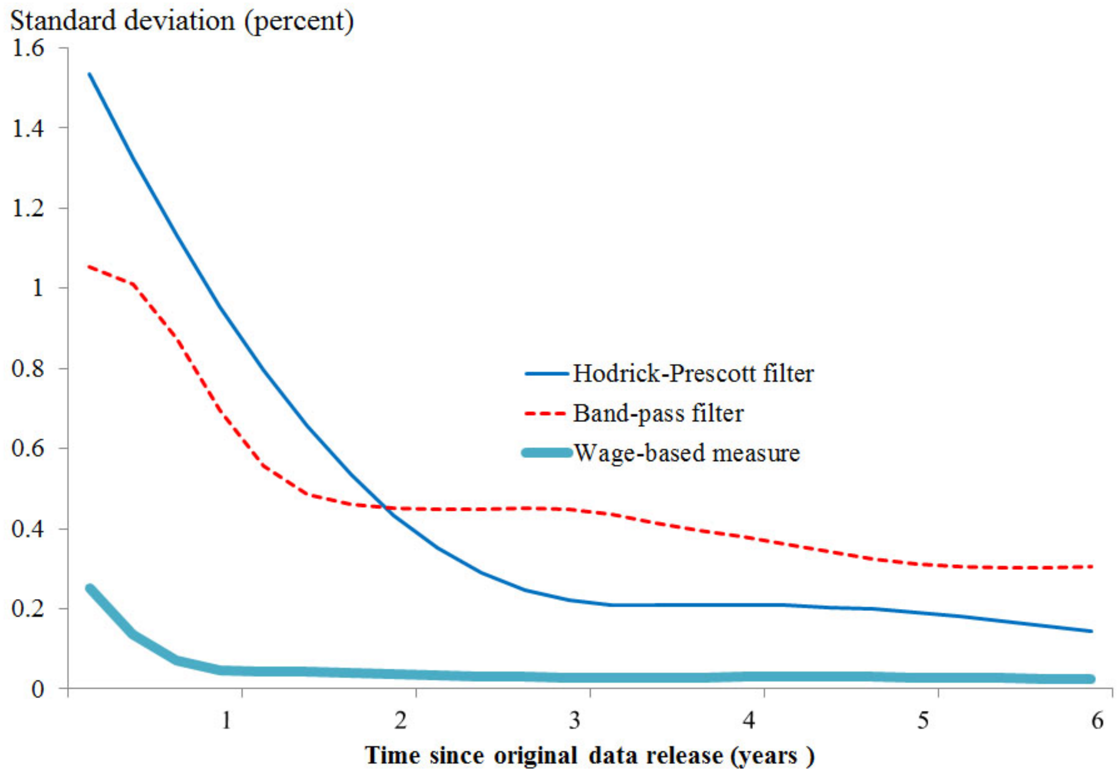
SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, author's calculations.

Figure 9: Instability of the Hodrick-Prescott Measure of the Output Gap



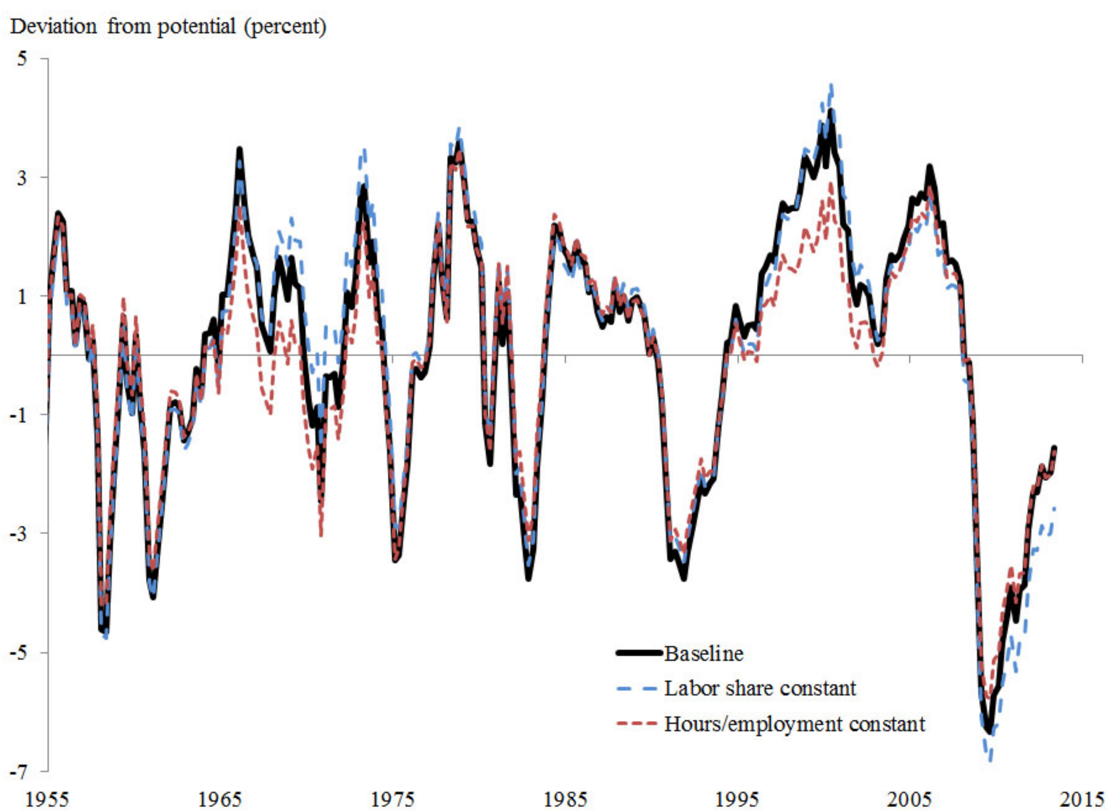
SOURCES: Bureau of Economic Analysis, Bureau of Labor Statistics, author's calculations.

Figure 10: Uncertainty of Output Gap Measures Fades When New Data Are Released



SOURCE: Author's calculations.

Figure 11: Output Gap Measure Robust to Shifts in Labor Share and Hours per Worker



SOURCES: Bureau of Labor Statistics, author's calculations.

To further illustrate this point I compute the RMSE of the output gap as a function of the time lag between the current period (that is, the period for which the latest data are available) and the period for which the output gap is estimated. I average these errors for all current periods starting with 1971 (allowing an initial period to initialize the estimation and fix the normalization). Figure 10 plots the RMSE as a function of the time lag for the HP-filter, the band-pass filter, and for my wage-based measure of the output gap. It shows that it takes at most three quarters for my measure to stabilize around the final estimate, with the real-time error on the order of 0.2 percent. However, the average real-time error in the output gap produced by the HP-filter starts at 1.5 percent and takes more than three years to stabilize. Moreover, it is not until almost a decade later that the HP-filter becomes as robust as my wage-based real-time estimate of the output gap.

Robustness Analysis. I also briefly discuss the robustness of my estimates to the assumptions regarding long-run stability of hours per worker and the labor shares. For robustness analysis I generate an artificial data series for hours worked, which are by construction constant fractions of employment. Similarly, I generate an artificial data series for labor compensation, which is assumed to be a constant fraction of GDP. In each case, I replace the actual data by the artificial data series and re-compute my estimate of the output gap. The difference between the baseline estimate of the output gap and the estimates based on artificial data gives a perfect estimate of the error that might be introduced by using the assumptions. Figure 11 compares all three estimates. It shows that the standard error of each of the assumptions does not exceed half a percentage point. The estimate of the standard error introduced by both of these assumptions jointly is 0.51 percent.

5. CONCLUSION

My wage-based measure of the output gap both satisfies basic economic intuition and remains virtually unchanged when new data are released. It is highly robust to deviations from the underlying assumptions employed in its construction. This makes the wage-based measure of the output gap a reliable tool for understanding current economic conditions and guiding policymaking. The methodology may also prove useful in academic research for detrending GDP and other macroeconomic time series, both for the U.S. and other countries.

However, caution must be expressed regarding data revisions, which may lead to sizable changes in the estimate of the output gap. For instance, the 2013 revision of national accounts going all the way back to 1929 resulted in a 1 percent upward revision of the output gap. This change translated one-to-one from the revision of the path of real GDP. Unfortunately, no method of constructing the output gap can insulate from such data revisions.

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