ASSESSING THE STATE OF THE ECONOMY IN REAL TIME USING HEADLINE ECONOMIC INDICATORS

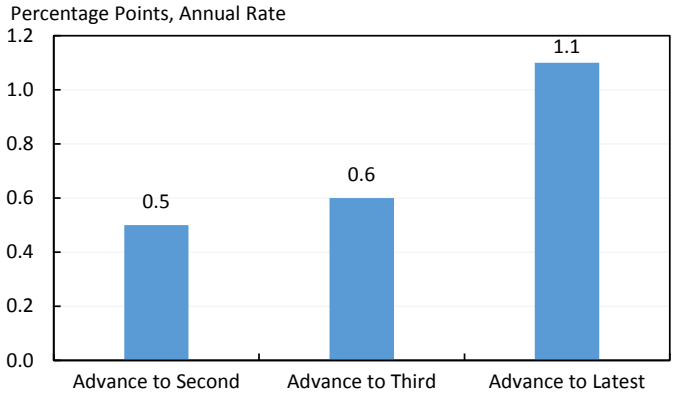
Measuring the position of the U.S. economy in real time is difficult, both because there is no single comprehensive indicator of the state of the economy and because the many existing measures that do exist capture different aspects of the economy and are subject to frequent (and large) revisions. This issue brief presents new analysis by the Council of Economic Advisers on how to best weight different preliminary headline measures in assessing the state of the U.S. economy in real time. The analysis finds that employment growth is best measured solely using data from the payroll survey and ignoring estimates of changes in employment levels from the household survey altogether. It also finds that, in understanding the current state of the economy, data on both employment growth and output growth are useful—with substantially more weight, roughly two-thirds or more, given to headline estimates of employment growth and less weight, roughly one-third or less, given to headline estimates of output growth.

Introduction

The U.S. economy, is large, dynamic, and complex, and measuring it in real time is difficult. One challenge is that there are many possible indicators of the state of the economy to consider. Headline indicators—like employment growth and GDP growth—often attract the most attention, but can send different signals regarding the state of the economy. A second challenge is that indicators of the overall strength of the economy depend on large and often complicated surveys of households and businesses that, like all statistical surveys, are subject to sampling error and other forms of unavoidable imprecision. A third challenge is that when analyzing the economy in real time one must decide how much influence any one indicator should have in the assessment of the economy. This issue brief present new analysis on how best to judge the state of the economy based on some of the most commonly cited economic indicators.

In an effort to balance the timeliness and accuracy of data, the Federal statistical agencies—including the Bureau of Economic Analysis (BEA), the Bureau of Labor Statistics (BLS), and the Census Bureau—frequently revise their estimates of economic indicators as newer, more complete, and better underlying data become available. These revisions can often be large and meaningful. For example, advance estimates of quarterly real gross domestic product (GDP) growth by the BEA are released before the Bureau has full data on trade, inventories, and services spending. As these (and other) data become available, BEA releases two more estimates of growth for each quarter, and revises several years' worth of data each July. Together, these revisions can have a dramatic effect on measured economic growth: the average absolute revision from the advance to the latest estimate[1] is more than a full percentage point (the equivalent of nearly $200 billion at an annual rate), as shown in Figure 1.

Figure 1: Average Absolute Revisions to Quarterly Real GDP Growth



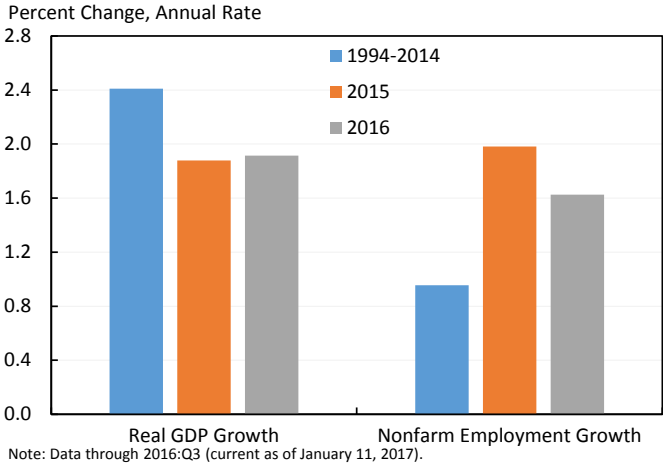
Note: Data from 1993 to 2015. "Latest" estimates are current as of January 11, 2017.
Source: Bureau of Economic Analysis.

Even if one knew immediately what real GDP growth was in a given quarter, it may not be the best or only measure of the cyclical position of the economy. No single comprehensive measure of the state of the economy

[1] Throughout this issue brief, "latest" estimates are those that are current as of January 11, 2017.

exists, and existing indicators, which measure different aspects of the economy, can send different (or even contradictory) signals. For example, while job growth in 2015 and 2016 has been well above its pace over the prior 20 years, real GDP growth has been slower, as Figure 2 shows. While some of this divergence is likely due to a slowdown in productivity growth and shifts in demographics, it illustrates how difficult it can be to gauge the underlying state of the economy from existing indicators.

Figure 2: Real GDP and Nonfarm Employment Growth



Note: Data through 2016:Q3 (current as of January 11, 2017).
Source: Bureau of Economic Analysis; Bureau of Labor Statistics; CEA calculations.

Given both the uncertainty inherent in any statistical measure and the standard practice of revising estimates, it is often better to look at multiple sources of data when assessing the state of the U.S. economy in real time. It is important to note, though, that not all measures contain the same amount of uncertainty: some first-reported estimates come from surveys with large sample sizes and tend to be revised less, while others contain a larger number of statistical assumptions and consequently may undergo more substantial revisions. Others may be largely unrevised over time, but contain a sizable error margin due to sampling or other survey issues. Consequently, when attempting to understand the current position of the U.S. economy in real time, one should not necessarily weight all current measures equally.

This issue brief presents new analysis by the Council of Economic Advisers (CEA) on how to best weight different preliminary headline measures of major economic data in assessing the state of the U.S. economy in real time. In each case, we construct weighted averages of preliminary data and compare these averages to some "latest" measure (that is, one that has undergone a large number of revisions), and then determine the optimal weighting that minimizes the difference between our predicted "latest" measure and the actual "latest" measure. (For more details on CEA's econometric methodology, see the accompanying Technical Appendix.)

CEA's analysis finds:

- The magnitude of employment growth is best measured solely using data from the payroll survey and ignoring estimates of changes in employment levels from the household survey altogether.

- The unweighted average of GDP and gross domestic income (GDI)—a concept that CEA calls "gross domestic output" (GDO)—is more predictive both of revisions to current-quarter growth and of output growth in future quarters than either GDP or GDI alone. (The results of this analysis were reported in an earlier issue brief [CEA 2015a] and are not repeated here.)

- In understanding the current state of the economy, data on both employment growth and output growth are useful—with substantially more weight, roughly at least two-thirds, given to employment growth and less weight, less than one-third, given to output.

It is important to note that the analysis contained in this issue brief is not intended to present optimal methods of forecasting macroeconomic aggregates given a comprehensive set of all available preliminary data. Instead, it is meant to provide heuristics for understanding the current state of the economy using the most commonly cited headline measures.

Monthly Employment Growth: Household or Payroll?

Each month, the Bureau of Labor Statistics (BLS) releases data on the state of the U.S. labor market that are based on two different surveys. The first is known as the "establishment" or "payroll" survey, and is derived from a sample of more than 400,000 worksites covering about a third of total nonfarm employment in the United States. The second, the "household" survey (officially, the Current Population Survey), samples approximately

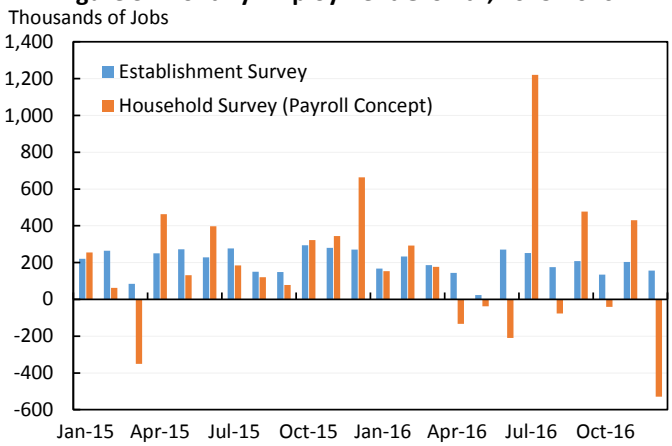
60,000 households each month and asks household members about their employment status in the previous month. Both the unemployment rate and the labor force participation rate—important indicators of the state of the labor market—are derived from the household survey. Economists and other analysts generally place the most emphasis on the estimate of the over-the-month change in jobs that is based on the payroll survey.

The household survey also provides an estimate of the change in the level of employment that many analysts incorporate into their assessment of the overall state of the labor market. For example, in May 2012, the first estimate of the establishment survey reported 69,000 jobs added, but the household survey reported a much stronger 422,000 jobs added. Even though most analysts agree that the establishment survey estimate is superior, many would argue that both estimates contain useful information, and thus that the truth was likely more positive than the establishment survey would have indicated for that month. The purpose of the analysis contained in this issue brief is to assess the relative weight the two measures should have in our understanding of monthly changes in job growth. (Regardless of the answer to this question, the ratios presented in the household survey—like the unemployment rate—are still important economic indicators in their own right and do not suffer from some of the issues that affect level changes from the household survey, insofar as errors in the numerator and denominator of these ratios cancel out.)

The household and payroll estimates differ somewhat conceptually. In particular, the household concept of total employment includes individuals who are self-employed, who work without pay, and who work on farms, and also counts those with multiple jobs as a single employed person.

However, even after adjusting for these conceptual issues, the two estimates often differ substantially in any given month. Figure 3 shows monthly estimates from each of the two series in 2015 and 2016, using a modified series for the household survey published by BLS with an employment concept similar to that used in the establishment survey. As the figure shows, conceptual differences alone cannot account for the often-large differences between the two surveys' estimates of monthly job growth.

Figure 3: Monthly Employment Growth, 2015-2016



Note: Data are current as of January 11, 2017.
Source: Bureau of Labor Statistics; CEA calculations.

As Figure 3 shows, the establishment survey tends to show a much steadier trend of job growth than the household survey. In large part, this is due to the establishment survey's much larger sample size. However, the establishment survey is still not a perfect measure of total employment in the United States. In addition to the statistical noise inherent in any sample-based estimate, the establishment survey also incorporates a model-based estimate of establishment births and deaths (since neither are sampled directly under current survey methods) that is a cause of additional measurement error.

Moreover, monthly job growth estimates from the payroll survey are revised in each of the two months following their initial release based on more complete reporting, including late responders. Estimates are further revised in subsequent years based on data from the Quarterly Census of Employment and Wages (QCEW), a near-complete count of all nonfarm employment in the United States compiled from tax records from the unemployment insurance system. (Revisions to the household survey are far smaller, and consist solely of annual updates to seasonal adjustment factors, not to actual survey data.)

In principle, then, both the household and establishment measures of job growth could contain information about the true underlying path of U.S. employment (conceptual issues aside). However, CEA analysis finds that in practice the household survey is so volatile that it contains almost no additional information about monthly changes in employment beyond that contained in the establishment survey.

To assess the information content in preliminary establishment and household estimates relative to "true" underlying monthly employment growth, CEA used three different methods. The first assumes the only error in the two measures derives from sampling and that these errors are uncorrelated. Given the known sampling errors, the optimal combination of the two is based on weights inversely proportional to the respective standard deviations—which produces a weight of 96 percent on the payroll survey and 4 percent on the household survey. Moreover, the additional improvements from incorporating the household survey are small.

The second method assumes that the underlying "truth" about the economy is relatively smooth—so that large month-to-month variations in job growth are more likely to be artefacts of measurement error than revelations about the underlying truth of the economy. This method solves for the relative weights on the payroll and household surveys that minimize this monthly variance, which are 93 percent and 7 percent, respectively. Moreover, as noted above, the additional improvements from incorporating some household information are very small. (Of course, there is no reason to necessarily assume that underlying monthly changes in the level of employment are smooth, but this method is provided as one of several that reaches similar conclusions.)

Finally, the third method calculates the optimal weighting to place on first-reported estimates of monthly job growth from each survey when predicting the following three variables, which in each case is assumed to be the "true" value for monthly changes in employment:

- The "latest" payroll survey estimate;
- The "latest" household survey estimate; and
- Predicted values from a statistical procedure called a "state-space model" that extracts an unobserved component that is common to, and explains as much as possible of movements in, "latest" estimates from both the payroll and household surveys.

The optimal weighting is defined as the weighting of variables that results in the smallest standard deviation in the prediction error of the true state of the economy. The results of this analysis are shown in Table 1 and Figure 4.[2] As both the table and figure show, one should optimally put 100 percent on first-reported payroll-survey estimates when attempting to predict the latest monthly estimates from the payroll survey. Even in predicting the latest household survey estimate, though, one should place about 21 percent weight on the payroll survey, indicating that it contains some information about true household employment that earlier estimates from the household survey itself do not—which is remarkable given that the only revisions to household survey estimates are based on changes in seasonal adjustment. When using a state-space model, one should place approximately 92 percent of weight on the payroll estimate. Importantly, compared with this optimal weighting, there is very little accuracy lost in predicting the state-space model output using the payroll survey alone.

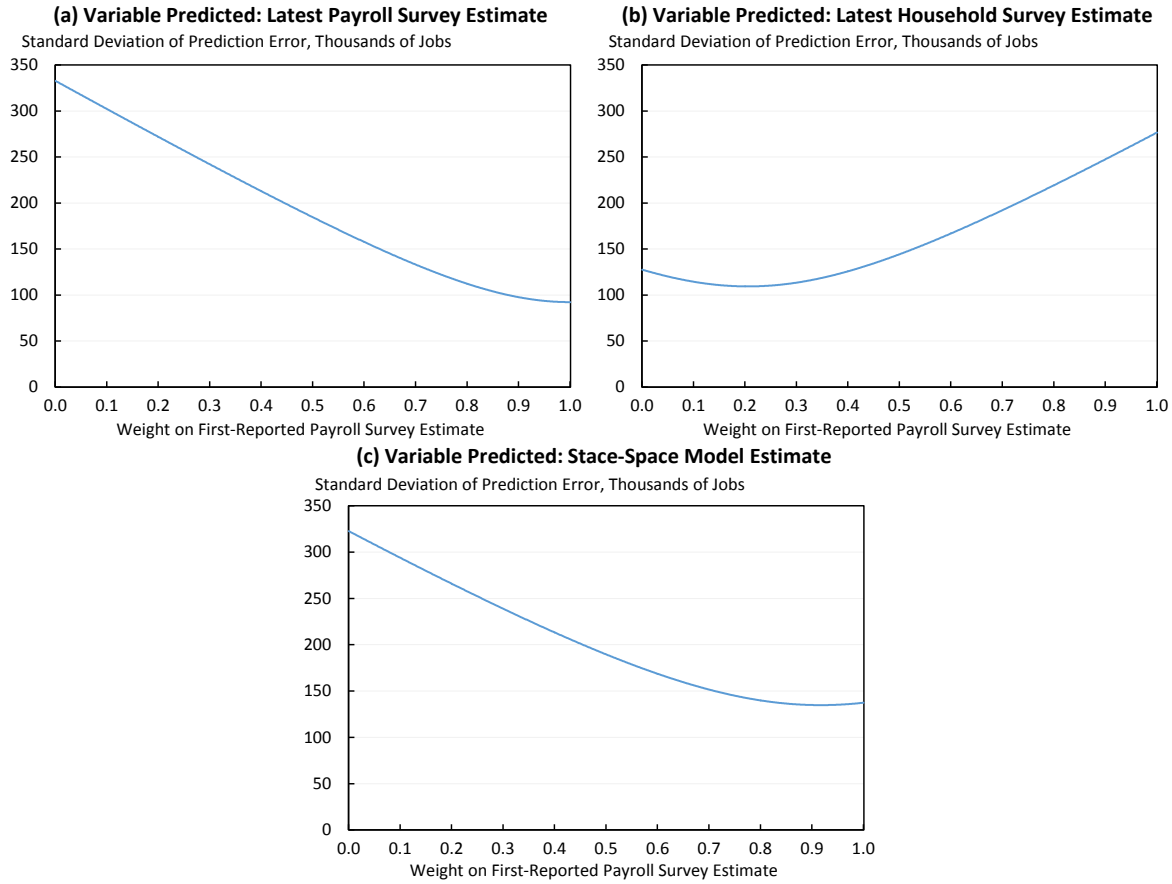
[2] This analysis excludes estimates from January of each year in the sample, since estimates from the household survey are updated with new population controls each January, causing trend breaks in estimated total employment levels (and thus large apparent changes in employment between December and January). However, CEA also replicated this analysis using a research series from BLS that smooths these annual trend breaks. The results are nearly identical to those presented here; however, we chose to focus on the "headline" household survey in our main analysis, since it, and not the research series estimate, is the most commonly cited figure of employment growth from the household survey.

Table 1: Optimal Weighting of Headline Measures in Predicting Monthly Changes in Employment

Variable Predicted	Optimal Weight on First-Reported Household Estimate	Optimal Weight on First-Reported Payroll Estimate	Standard Deviation of Error/Prediction Using Optimal Weighting (Thousands of Jobs)	Standard Deviation of Error/Prediction Using Only Payroll Estimate (Thousands of Jobs)
Latest Payroll Estimate	0.00	1.00	92	92
Latest Household Estimate	0.79	0.21	109	277
State-Space Model Estimate	0.08	0.92	135	137

Note: Data from Jan-1994 to Dec-2014. Excludes data for January in each year due to trend breaks in household survey estimates. "Latest" estimates are current as of January 11, 2017.
Source: Bureau of Labor Statistics; CEA calculations.

Figure 4: Weighting of Headline Measures in Predicting Monthly Changes in Employment



Note: Data from Jan-1994 to Dec-2014. Excludes data for January in each year due to trend breaks in household survey estimates. "Latest" estimates are current as of January 11, 2017.
Source: Bureau of Labor Statistics; CEA calculations.

Given that the latest payroll estimates incorporate near-complete counts of employment from the QCEW, they are more likely to reflect true underlying employment growth than the latest household estimates, which do not incorporate any additional underlying data. Additionally, state-space model analysis, which measures the unobserved underlying trend in employment growth data, indicates that a small amount of weight should be placed on preliminary household estimates. As such, this method also finds that the contemporary state of the labor market is best measured solely using preliminary payroll survey data and ignoring household-survey estimates altogether.

The Overall State of the Economy: Output or Employment Data?

More generally, it is possible to combine real-time measures of economic output (GDP, GDI, and GDO, which is an equal-weighted average of the former two) with real-time measures of employment growth to gain a more accurate assessment of broad economic conditions on a quarterly basis. This is particularly important given that quarterly estimates of output growth undergo extensive revisions across multiple years as new and more complete data on real economic activity become available to BEA (Figure 1).

Additionally, as noted above, employment and output data can sometimes show contradictory signals about the state of the economy. In the first quarter of 2014, for example, real GDO increased 0.4 percent at an annual rate, while total nonfarm employment increased 1.5 percent at an annual rate. Although some of this divergence is likely due to real changes in underlying productivity, the divergence between employment and output estimates also reflects a combination of conceptual differences and measurement error.

As with the analysis of employment growth above, one possible way to assess the relative information content in preliminary output and employment data relative to the "true" underlying state of the economy is make the (admittedly strong) assumption that the underlying "truth" is relatively smooth. Solving for the relative weights on preliminary payroll and output estimates that minimize quarterly variance yields between 74 and 86 percent for payroll data, and between 14 and 27 percent for output data, depending on the particular measure of output growth used.[3]

In measuring the "true" state of the overall economy that proxies for the concept of broad economic conditions of interest we consider multiple measures of quarterly economic activity: the payroll survey estimate of nonfarm employment growth, growth in real GDO (which previous work finds is the nearly-optimal combination of GDP and GDI [see CEA 2015a]), a state-space model combining payroll employment growth and real GDO growth, and three broad-based indexes of economic indicators from the Federal Reserve Bank of Chicago, the Federal Reserve Bank of Philadelphia, and the Conference Board. The latter three indexes are coincident indicators estimated using a number of time series:

- The Chicago Fed National Activity Index (CFNAI) is a broad measure of economic activity extracted from 23 series on production and income, 24 series on employment and hours, 15 series of consumption and housing, and 23 series on sales, orders and inventories. The index is the first principal component of the 85 series, or an estimate of the movements in the 85 series that is common across all variables.[4]

- The Conference Board Coincident Economic Indicators index is the modern version of the classic Burns-Mitchell approach to business cycle indicators. The indicator uses four variables (payroll employment, personal income, industrial production, and manufacturing and trade sales). The data are smoothed and weighted.

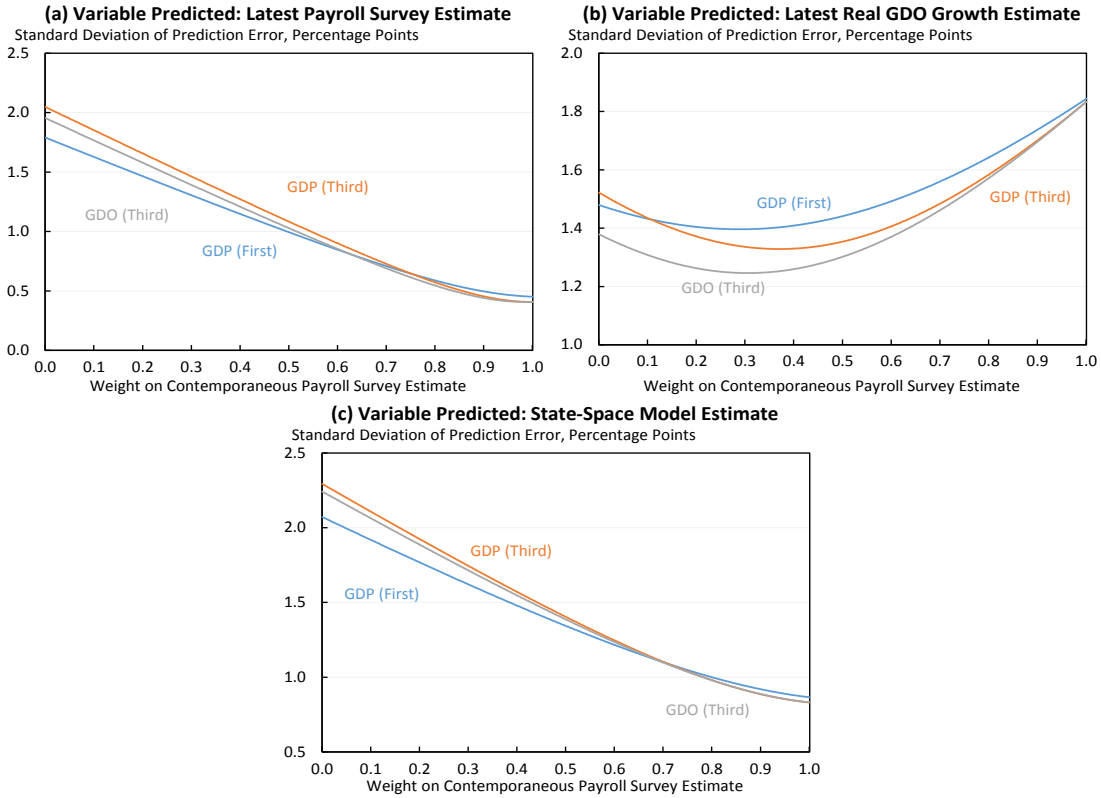
- The Philadelphia Fed Current Economic Activity Index combines payroll employment, the unemployment rate, average hours worked, and manufacturing wages and salaries.

The latter two combination indexes include payroll employment as one of a handful of series, and do not include a direct measure of GDP growth. This may tilt the estimates towards finding that payroll employment does the best job explaining movements in these series. The CFNAI, though, includes a wide range of employment and output data and seems a neutral test of which can better gauge the state of the economy.

[3] Using the first estimate of GDP yields the lowest weight on payroll employment data (74 percent), while using the third estimate of GDO (see footnote 6 below) results in the highest (86 percent).

[4] The index is constructed using the Stock and Watson (1999) methodology for measuring aggregate activity based on a large number of economic indicators.

Figure 5: Weighting of Headline Measures of Output and Employment Growth in Predicting Quarterly Changes in Macroeconomic Aggregates



Note: Data from 1994:Q1 to 2014:Q4. Series labels indicate the measure of real output growth (and the vintage of the estimate) used in predicting the variable of interest. "Latest" estimates are current as of January 11, 2017.
Source: Bureau of Economic Analysis; Bureau of Labor Statistics; CEA calculations.

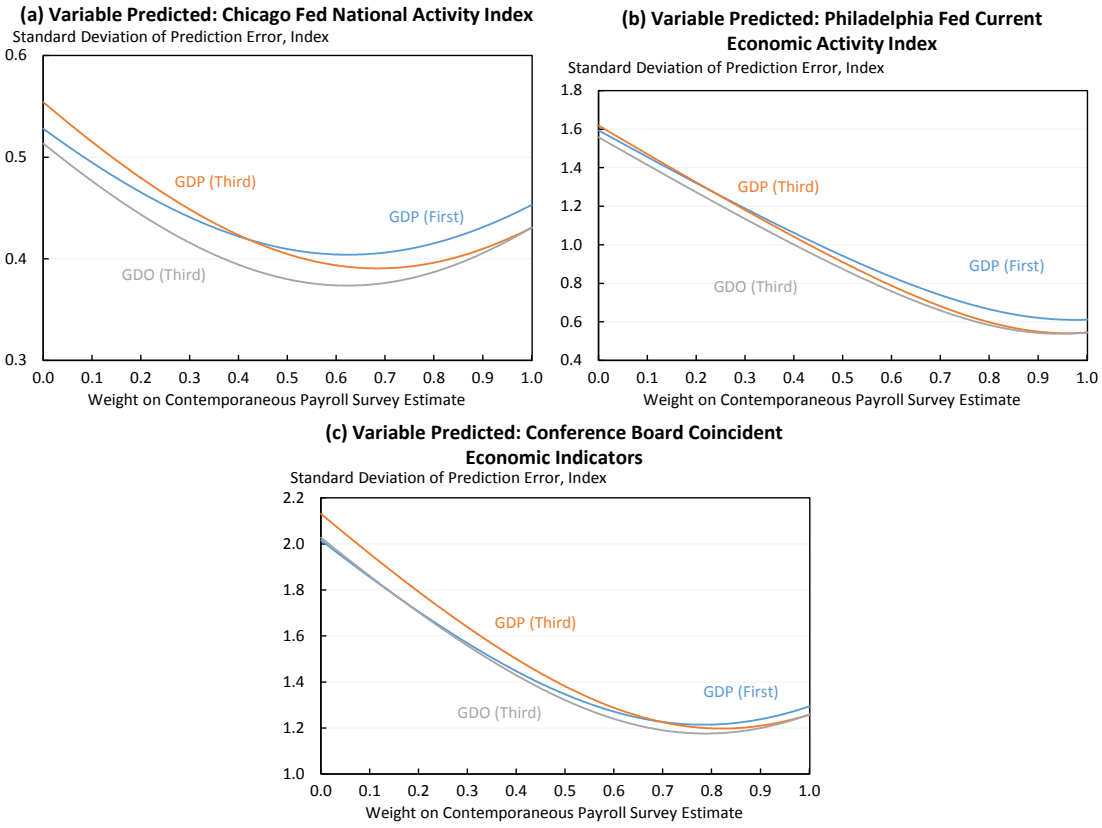
In each case, a given estimate of output growth (either the first or third estimate of real GDP growth or third estimate of real GDO growth[5]) is combined in a weighted average with the payroll-survey estimate of employment growth available at the time of the output estimate's release. Optimal weights are determined as the weights that minimize the prediction error of the proxy for the "true" state of the economy.[6]

If the truth is assumed to be the latest version of payroll employment growth, then the optimal prediction places all of the weight on the initial estimates of employment growth (Figure 5a). This assumption about the truth, of course, biases the results towards putting substantial weight on the payroll survey. But interestingly, if the truth is assumed to be the latest version of GDO—an assumption that heavily biases the results towards putting substantial weight on initial estimates of output—then the optimal prediction still places 29 to 37 percent of the weight on the early estimates of payroll growth (Figure 5b). These two methods strongly suggest that payroll growth contains substantial information. In fact, if—instead of arbitrary assumptions about which series constitutes the truth—we instead use a state-space model to construct the truth as a combination of the latest estimates of both payroll and output data, then we find that the optimal prediction places 100 percent of the weight on the payroll survey (Figure 5c). This result does not change if the third estimate of GDO or the third estimate of GDP is used in the estimates.

[5] Estimates of GDO are typically released one month behind estimates of GDP for a given quarter. In the analysis that follows, the "third estimate of GDO" refers to the estimate of GDO released at the same time as the third estimate of GDP.

[6] The analysis that follows uses the payroll-survey estimate as the preferred measure of employment growth. Consistent with the finding in the first part of this issue brief that the payroll measure is generally superior for assessing the state of the labor market, replace payroll estimates with household estimates in the analysis results in less weight placed on employment data (and more weight placed on output data) and less-accurate predictions of both macroeconomic aggregates and indexes of economic activity.

Figure 6: Weighting of Headline Measures of Output and Employment Growth in Predicting Quarterly Changes in Broad Indexes of Current Activity



Note: Data from 1994:Q1 to 2014:Q4. Series labels indicate the measure of real output growth (and the vintage of the estimate) used in predicting the variable of interest. "Latest" estimates are current as of January 11, 2017.
Source: Bureau of Economic Analysis; Bureau of Labor Statistics; Federal Reserve Bank of Chicago; Federal Reserve Bank of Philadelphia; Conference Board; CEA calculations.

If the broader measures of the state of the economy are used as proxies for its true state, then the majority of the weight in predicting that true state goes to preliminary payroll employment. These indexes put varying weights on labor-market indicators relative to other measures of real activity, and the optimal weights on payrolls in our exercise tend, unsurprisingly, to broadly track the weight that each index assigns to labor market data. If we use the CFNAI, which has limited employment data and many other real variables, our exercise still assigns a nearly two-thirds weight on payroll employment (Figure 6a). If we use the Philadelphia Fed index, which places considerable weight on establishment survey data, our exercise assigns an optimal weight on payrolls of almost 100 percent (Figure 6b). If we use the Conference Board index, in which employment constitutes one-quarter of the index (1 of 4 variables), our exercise assigns an 80-percent weight to preliminary payroll data (Figure 6c).

This optimal weighting exercise places a substantial emphasis on the information contained in the early payroll estimates of employment growth, regardless of which measure of output we use. This is particularly true when predicting post-revision employment growth—where early output estimates contribute no information beyond that contained in early payroll estimates—but is also true even when assessing output growth. Even when predicting post-revision real GDO growth, one should still place approximately one-third weight on contemporaneous measures of nonfarm employment growth. Optimal weighting for predicting the broader measures of economic activity vary somewhat from index to index, but in all cases more emphasis is placed on early estimates of employment growth than on early estimates of output growth (Table 2).

Table 2: Weighting of Headline Measures of Output and Employment Growth in Predicting Quarterly Changes in Macroeconomic Aggregates and Broad Indexes of Current Activity

Variable Predicted	Real Output Measure	Optimal Weight on Output Measure	Optimal Weight on Contemporaneous Payroll Estimate	Standard Deviation of Error Using Optimal Weighting
Latest Payroll Employment Growth Estimate	GDP (First)	0.00	1.00	0.45
	GDP (Third)	0.00	1.00	0.41
	GDO (Third)	0.01	0.99	0.41
Latest Real GDO Growth Estimate	GDP (First)	0.71	0.29	1.40
	GDP (Third)	0.63	0.37	1.33
	GDO (Third)	0.69	0.31	1.25
State-Space Model Estimate	GDP (First)	0.00	1.00	0.87
	GDP (Third)	0.00	1.00	0.83
	GDO (Third)	0.00	1.00	0.83
Chicago Fed NAI	GDP (First)	0.38	0.62	0.40
	GDP (Third)	0.32	0.68	0.39
	GDO (Third)	0.38	0.62	0.37
Philadelphia Fed CEAI	GDP (First)	0.02	0.98	0.61
	GDP (Third)	0.04	0.96	0.54
	GDO (Third)	0.06	0.94	0.54
Conference Board CEI	GDP (First)	0.22	0.78	1.21
	GDP (Third)	0.18	0.82	1.20
	GDO (Third)	0.21	0.79	1.18

Note: Data from 1994:Q1 to 2014:Q4. "Latest" estimates are current as of January 11, 2017.
Source: Bureau of Economic Analysis; Bureau of Labor Statistics; Federal Reserve Bank of Chicago; Federal Reserve Bank of Philadelphia; Conference Board; CEA calculations.

Conclusion

The analysis in this issue brief has focused on understanding the current state of the economy based on contemporaneous data, not predicting its future. In previous research, CEA has found (again, using only commonly cited headline data), that the best predictor of real GDP growth one quarter ahead is the growth of real private domestic final purchases (PDFP), the sum of consumption and fixed investment. By excluding changes in more volatile components of GDP—inventory investment, net exports, and government spending—real PDFP growth ignores transitory (albeit actual) changes in the economy that are unlikely to persist and thus are less reflective of underlying trends in economic growth (CEA 2015b).

No single measure of the economy is perfect, and all measures are subject to measurement error and conceptual challenges. A fuller analysis of both assessing the current state of the economy and predicting its future would, of course, entail looking at a much wider range of variables and models. However, the analysis in this issue brief is intended to provide some simple rules of thumb for interpreting several of the most frequently cited headline economic indicators.

These results suggest that, to a first approximation, much more emphasis should be placed on contemporaneous estimates of employment growth than on contemporaneous estimates of output growth when attempting to assess the overall current state of the U.S. economy. Moreover, employment growth itself is best measured entirely using the payroll survey while disregarding changes in the household-survey measure of employment.

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Technical Appendix

To find the weight to assign to preliminary data when seeking to best predict some "latest" measure of the state of the economy, we start with an equation that weights the two preliminary measures to predict the latest, or "true" measure of interest. For the employment optimal weighting this begins with an equation that links the latest employment (*emp*) measure of interest with the preliminary (*pre*) measure, where *HH* stands for household concept and *PR* for payroll concept. The key parameter to be found is γ, which measures the weight given to a preliminary measure.

$$emp_t^{latest} = \gamma \times emp_t^{HH,pre} + (1 - \gamma) \times emp_t^{PR,pre} + \varepsilon_t$$

The optimal weight is the one that minimizes the standard deviation of the prediction error. Here, that is the γ that minimizes stdev(ε_t). The solution to this problem is found by solving for the stdev(ε_t) for a sequence of γ's and choosing the γ that yields the lowest standard deviation of the prediction error.

A similar procedure is used for determining the optimal weighting when combining output (*out*) and employment (*emp*) data. Here, we use the equation:

$$out_t^{latest} = \gamma \times emp_t^{pre} + (1 - \gamma) \times out_t^{pre} + \varepsilon_t$$

(Both output and employment estimates are expressed as annualized quarterly percent changes.) Optimal weights for γ are again found by minimizing the standard deviation of the prediction error in this equation. A similar formula is used when employment is the measure of the true state of the economy, swapping latest output with latest employment in the equation above.

When using indexes of economic activity we need to run two preliminary regressions so that all variables are consistently measured in the same units. In this case we estimate:

$$activity_t^{final} = \alpha + \beta \times out_t^{pre} + \varepsilon_t$$

$$activity_t^{final} = \psi + \mu \times emp_t^{pre} + \varepsilon_t$$

Then the predicted index value based on output is:

$$\widehat{activity}_t^{out} = \hat{\alpha} + \hat{\beta} \times out_t^{pre}$$

Where ^ over regression coefficients represent OLS estimates, and ^ over variables represent predictions. Likewise, the predicted index value based on employment is:

$$\widehat{activity}_t^{emp} = \hat{\psi} + \hat{\mu} \times emp_t^{pre}$$

We then form the predictive equation for the "true" state of the economy as:

$$activity_t^{final} = \gamma \times \widehat{activity}_t^{out} + (1 - \gamma) \times \widehat{activity}_t^{emp} + \varepsilon_t$$

The optimal weight is solved as above to minimize the standard deviation of the prediction error.

State Space Model

Let S_t denote the true, unknown state of the economy (or labor market). Assume that this true state evolves as an autoregressive process:

$$S_t = \rho \times S_{t-1} + \epsilon^S{}_t$$

The latest estimates of employment and output (or household and payroll estimates of employment) are a linear function of this state with idiosyncratic errors, which are assumed to be autocorrelated processes:

$$emp_t^{final} = \theta^{emp} \times S_t + u^{emp}{}_t$$
$$out_t^{final} = \theta^{out} \times S_t + u^{out}{}_t$$

The first of these three equation is known as the "state equation," and the second and third as

"measurement equations." Using data on employment and output the likelihood function of the model can be computed using the Kalman filter, which in turn allows for numerical computation of the maximum likelihood estimators of the model parameters. Given these estimators, the Kalman smoother can be used to compute the optimal estimate of S_t.[7]

[7] For more details, see Hamilton (1994).