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Paper presented at the 13th Jacques Polak Annual Research Conference
Hosted by the International Monetary Fund
Washington, DC—November 8–9, 2012

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Okun's Law: Fit at 50?

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November 1, 2012

This paper asks how well Okun's Law fits short-run unemployment movements in the United States since 1948 and in twenty advanced economies since 1980. We find that Okun's Law is a strong and stable relationship in most countries, one that did not change substantially during the Great Recession. Accounts of breakdowns in the Law, such as the emergence of "jobless recoveries," are flawed. We also find that the coefficient in the relationship—the effect of a one percent change in output on the unemployment rate—varies substantially across countries. This variation is partly explained by idiosyncratic features of national labor markets, but it is not related to differences in employment protection legislation.

In 1962, Arthur Okun reported an empirical regularity: a negative short-run relationship between unemployment and output. Many studies have confirmed this finding, and Okun's Law has become a fixture in macroeconomics textbooks. For the United States, many authors posit that a one percent deviation of output from potential causes an opposite change in unemployment of half a percentage point (for example, Mankiw, 2012).

Yet many economists question Okun's Law. Observers have suggested that each of the last three U.S. recessions was followed by a "jobless recovery" in which unemployment did not fall as much as Okun's Law predicts. Studies of international data suggest that Okun's Law is unstable in many countries (for example, Cazes et al., 2011). Some find that the relationship broke down during the Great Recession of 2008-2009, when there was little correlation across countries between the changes in output and unemployment (for example, IMF, 2010).

These claims matter for the interpretation of unemployment movements and for macro policy. Okun's Law is a part of textbook models in which shifts in aggregate demand cause changes in output, which in turn lead firms to hire and fire workers. In these models,

¹ Ball: Johns Hopkins University; Leigh and Loungani: International Monetary Fund. We are grateful to Olivier Blanchard, Dan Citrin, Mai Chi Dao, Davide Furceri, Michael Goldby, Juan Jimeno, Akito Matsumoto, and participants at an IMF Research Department seminar for helpful comments and suggestions, and to Jair Rodriguez for excellent research assistance. The views expressed in this paper are those of the authors and do not necessarily represent those of the IMF or IMF policy.

when unemployment is high, it can be reduced through demand stimulus. Skeptics of Okun's Law question this policy view. McKinsey (2011), for example, argues that Okun's Law has broken down because of problems in the labor market, such as mismatch between workers and jobs. They stress labor market policies such as job training, not demand stimulus, as the key to reducing unemployment.

This paper asks how well Okun's Law explains short-run unemployment movements. We examine data for the United States since 1948 and for twenty advanced countries since 1980. Our principal conclusion is that Okun's Law is a strong and stable relationship in most countries. Deviations from Okun's Law occur, but they are usually modest in size and short-lived. Overall, the data are consistent with traditional models in which fluctuations in unemployment are caused by shifts in aggregate demand.

There is one important qualification to the universality of Okun's Law. While a stable Law fits the data for most countries, the coefficient in the relationship—the effect of a one-percent change in output on the unemployment rate—varies across countries. We estimate, for example, that the coefficient is -0.15 in Japan, -0.45 in the United States, and -0.85 in Spain. These differences reflect special features of national labor markets, such as Japan's tradition of lifetime employment and the prevalence of temporary employment contracts in Spain.

Section II of this paper introduces Okun's Law and alternative approaches to estimating it. The rest of the paper demonstrates the good fit of the relationship and points out common flaws in analyses that report breakdowns of the Law.

Section III considers U.S. data. We find that the U.S. Okun's Law has a coefficient of -0.4 or -0.5 , with an \bar{R}^2 in the neighborhood of 0.8. This finding is robust: it holds for different time periods, for both quarterly and annual data, and for various methods of measuring short-run movements in output and unemployment.

Section IV examines the common claim that U.S. recoveries since the 1990s have been "jobless." We find no evidence that Okun's Law broke down during these episodes. Confusion on this issue has arisen because output grew more slowly in recent recoveries than in earlier ones, causing high unemployment to linger. (Gali et al. 2012 make a similar point.)

Section V extends our analysis to international data. Okun's Law fits most advanced economies, although the typical \bar{R}^2 is somewhat lower than for the United States. The coefficient in the Law varies across countries, but it is relatively stable within a given country.

We generally do not find that the coefficient has risen over time, as some studies suggest (for example, IMF 2010).

Section VI examines the Great Recession of 2008-2009. A number of international studies suggest that Okun's Law broke down during this period, but once again we find that the Law holds up well. Apparent anomalies mostly disappear if we account properly for cross-country differences in the Okun coefficient and in the lengths of recessions.

Section VII seeks to explain the cross-country differences in Okun coefficients, with limited success. We propose explanations for the largest outliers, such as Spain and Japan, but we have not found a variable that explains the coefficients more generally. In particular, they are not correlated with the OECD's measure of legal employment protection, a variable suggested by previous authors. Section VIII concludes the paper.

II. ESTIMATING OKUN'S LAW

Here we introduce Okun's Law and discuss how we assess its fit to the data.

A. Okun's Law

We presume there exist some long-run levels of output, employment, and unemployment. We use the term "potential output" for long-run output, and the "natural rate" for long-run unemployment. Potential output is determined by the economy's productive capacity, and it grows over time as a result of technological change and factor accumulation. The long-run level of employment and the natural rate of unemployment are determined by the size of the labor force and by frictions in the labor market. When output is at its long-run level, employment and unemployment are also at their long-run levels.

Following Okun, we assume that shifts in aggregate demand cause output to fluctuate around potential. These output movements cause firms to hire and fire workers, changing employment; in turn, changes in employment move the unemployment rate in the opposite direction. We can express these relationships as

$$(1) \quad E_t - E_t^* = \gamma (Y_t - Y_t^*) + \eta_t, \gamma > 0;$$

$$(2) \quad U_t - U_t^* = \delta (E_t - E_t^*) + \mu_t, \delta < 0;$$

where E_t is the log of employment, Y_t is the log of output, U_t is the unemployment rate, and $*$ indicates a long-run level.

We can derive Okun's Law by substituting (1) into (2):

$$(3) \quad U_t - U_t^* = \beta (Y_t - Y_t^*) + \varepsilon_t, \beta < 0,$$

where $\beta = \gamma\delta$ and $\varepsilon_t = \mu_t + \delta \eta_t$. The coefficient β in Okun's Law depends on the coefficients in the two relationships that underlie the Law.

Past research provides guidance about the values of the parameters in equations (1)-(3). To see this, suppose first that changes in output and employment are movements along a neoclassical production function: more labor produces more output. For the United States, economists believe that the elasticity of output with respect to labor is about 2/3, based on factor shares of income. If we invert the production function, we get equation (1) with $\gamma = 3/2 = 1.5$.

However, as pointed out by Okun and by Oi (1962), labor is a quasi-fixed factor. It is costly to adjust employment, so firms accommodate short-run output fluctuations in other ways: they adjust the number of hours per worker and the intensity of workers' effort (which produces procyclical movements in measured productivity). Because of these other margins, we expect that γ , the response of employment to output, is less than the 1.5 suggested by a production function.

In equation (2), we expect the coefficient δ to be less than one in absolute value: unemployment moves less than one-for-one with employment. As Okun discussed, an increase in employment raises the returns to job search, which induces workers to enter the labor force. Procyclical movements in the labor force partly offset the effects of employment on the unemployment rate.

Combining these ideas, the coefficient in Okun's Law, $\beta = \gamma\delta$, should be less in absolute value than the coefficient γ in the employment equation, which itself is less than 1.5. Aside from these bounds, it is difficult to pin down the Okun coefficient a priori. It depends on the costs of adjusting employment, which include both technological costs such as

training and costs created by employment protection laws. The coefficient also depends on the number of workers who are marginally attached to the labor force, entering and exiting as employment fluctuates.

The error term ε_t in Okun's Law captures factors that shift the unemployment-output relationship. These factors include unusual changes in productivity or in labor force participation. Saying that "Okun's Law fits well" means that ε_t is usually small.

B. Estimation

In estimating Okun's Law, we take two approaches that Okun introduced in his original article. The first is to estimate equation (3), the "levels" equation. In this case, the tricky problem is to measure the natural rate U_t^* and potential output Y_t^* . In most of our analysis, we use the most obvious method: we smooth the output and unemployment series with the Hodrick Prescott (HP) filter. However, we also try a number of alternatives given the imprecision of the HP filter.

The other approach is to estimate the "changes" version of Okun's Law:

$$(4) \quad \Delta U_t = \alpha + \beta \Delta Y_t + \omega_t,$$

where Δ is the change from the previous period. Notice that this equation follows from the levels equation if we assume that the natural rate U^* is constant and potential output Y^* grows at a constant rate. In this case, differencing the levels equation (3) yields equation (4) with $\alpha = -\beta \Delta Y^*$, where ΔY^* is the constant growth rate of potential, and $\omega_t = \Delta \varepsilon_t$.

Equation (2) looks easier to estimate than equation (1), because it does not include the unobservables U_t^* and Y_t^* . For many countries, however, the implicit assumptions of a constant U_t^* and constant long-run growth rate are not reasonable. We think it is better to estimate U_t^* and Y_t^* as accurately as possible than to assume the problem away. In any case, both equations (1) and (2) fit the data well, but in most countries the fit is somewhat closer for the levels equation.

We estimate Okun's Law with both annual and quarterly data. With annual data, our specifications are exactly equations (3) and (4): we assume that the output-unemployment relationship is contemporaneous. With quarterly data, we find that the fit of our equations

improves if we include two lags of the output term. These lags capture the idea that it takes time for firms to adjust employment when output changes and for individuals to enter or exit the labor force.

III. OKUN'S LAW IN THE UNITED STATES

This section estimates Okun's Law for the United States over 1948-2011, checking robustness along several dimensions.

A. Annual Data: Main Results

Table 1 reports estimates of the levels equation (3) and the changes equation (4). We examine two versions of equation (3) with different series for U_t^* and Y_t^* , which we create by choosing different smoothing parameters in the HP filter. We try smoothing parameters of $\lambda = 100$ and $\lambda = 1,000$, the most common choices for annual data.

Our three specifications yield similar results. The estimates of the coefficient β are around -0.4 , and the \bar{R}^2 s are around 0.8. The levels equation with an HP parameter of $\lambda = 100$ yields the best fit, by a small margin (coefficient = -0.41 and $\bar{R}^2 = 0.82$).² Figure 1 illustrates the fit of Okun's Law by plotting $U_t - U_t^*$ against $Y_t - Y_t^*$, and the change in U against the change in Y. No year is a major outlier in the graphs.³

Some economists suggest that Okun's Law is non-linear, with different unemployment effects of increases and decreases in output (for example, Knotek, 2007). The scatter plots in Figure 1 suggest that a linear Okun's Law fits the data well. To confirm this result, we estimate separate coefficients for positive and negative output gaps in the levels equation, and for positive and negative output growth in the changes equation. We find no evidence of non-linearity. For example, for the levels equation with an HP parameter of $\lambda =$

² For all our regressions, we report ordinary least squares (OLS) standard errors. It is not clear whether robust standard errors are more reliable for our samples, many of which are small. In any case, we have also computed robust standard errors and they are generally close to the OLS standard errors.

³ When data for 2009 were released, a number of observers suggested that unemployment was significantly above the level implied by Okun's Law. Subsequently, this anomaly disappeared because output data for 2009 were revised downward (Elsby et al., 2011).

100, the estimated coefficients are -0.37 for positive output gaps and -0.39 for negative gaps; the p -value for the null of equality is 0.61.

Previous researchers also suggest that the coefficient in Okun's Law varies over time (for example, Meyer and Tasci, 2012). Once again, we find no evidence against our simple specification with a constant Okun coefficient. As Figure 1b reports, the sup-Wald test for a break in the Okun coefficient at an unknown date fails to reject the null of parameter stability for all three of our baseline specifications. The maximal F statistics are 5.30, 3.99, and 4.49, for the three specifications, respectively ($\lambda = 100$, $\lambda = 1,000$, and changes), well short of the 10 percent critical value of 7.12 calculated by Andrews (2003). We also estimate our equations separately for the first and second halves of our sample (1948-1979 and 1980-2011), and cannot reject equality of the two coefficients. For the levels specification with $\lambda = 100$, the coefficients are -0.35 for the first half and -0.41 for the second, and the p -value for the null of equality is 0.20. We also cannot reject equality when we estimate separate coefficients for each decade in our sample (p -value = 0.38).⁴ Finally, authors such as Meyer and Tasci (2012) and Owyang and Sepkhposyan (2012) estimate Okun's Law with rolling regressions and report substantial variation in the coefficient. Our results suggest, however, that changes in the coefficient are not statistically significant. In particular, as Figure 1c reports, rolling regressions based on 20-year and 30-year regression windows (with annual data) for our three specifications produce coefficient estimates whose 95 percent confidence always overlap, and always include the 95 percent confidence band of the full-sample estimates reported in Table 1.

B. Annual Data: Robustness

The biggest problem in estimating Okun's Law is that it includes the unobservable variables U_t^* and Y_t^* . Here we explore alternative approaches to this problem.

Addressing the Endpoint Problem

⁴ In this exercise, we include 1948-1949 in the decade of the 1950s and 2010-2011 in the decade of the 2000s.

It is well known that the HP filter, which we have used so far, is unreliable at the end of a sample. This problem is salient because the economic slump starting in 2008 has large effects on the HP estimates of U_t^* and Y_t^* . As shown in Figure 2a, for a smoothing parameter of $\lambda = 100$, the rise in actual unemployment pulls the estimated U_t^* from about 5 percent in the early 2000s to 8.7 percent in 2011. The growth rate of Y_t^* over 2008-2011 is 1.3 percent, well below the 2-3 percent rate considered normal before the Great Recession.

Some economists find such estimates plausible, believing that “structural” problems, such as mismatch between workers and jobs, have increased U_t^* and reduced Y_t^* . Yet many disagree, believing that recent movements in U_t and are mostly cyclical, and that U_t^* is lower and Y_t^* higher than the HP estimates. For example, both the Council of Economic Advisors and the Congressional Budget Office estimate that U_t^* was under 6 percent in 2011.

Therefore, to check robustness, we use a different approach to calculate U_t^* and Y_t^* at the end of the sample. We first estimate these variables from 1960 through 2007 by applying the HP filter to that period, with a smoothing parameter of $\lambda = 100$. In 2007, the estimated U_t^* is 4.9 percent, and the growth rate of Y_t^* (the change from 2006 to 2007) is 2.8 percent. We assume that U_t^* and the growth of Y_t^* remain constant at these levels over 2008-2011. That is, we attribute all of the increase in unemployment and growth slowdown after 2007 to transitory deviations from U_t^* and Y_t^* . Figures 2a and 2b compare the U_t^* and Y_t^* paths constructed this way to those based on the HP filter through 2011.

The scatter plot in Figure 2c shows how our alternative measures of U_t^* and Y_t^* affect the fit of Okun’s Law. Compared to the plot based entirely on the HP filter (Figure 1a), the observations for 2008-2011 move up and to the left. That is, unemployment is higher relative to the natural rate, and the output gap is more negative. But the regression has a coefficient of -0.40 , which is close to our baseline value of -0.41 , and the 2008-2011 observations are still near the line. Thus, Okun’s Law fits the data regardless of whether we interpret recent movements in unemployment and output as changes in long-run levels or deviations from long-run levels.

Forecast Errors

Another approach to testing Okun’s Law avoids the need to measure U_t^* and Y_t^* . Instead, we measure short-run fluctuations in U_t and Y_t with forecast errors. Specifically, we

examine deviations of four-quarter changes in output and unemployment from forecasts published by the Survey of Professional Forecasters. We assume that forecast errors reflect unanticipated shifts in aggregate demand, which should move unemployment and output in the proportion given by Okun's Law.

The sample covers forecasts made in Q1 of each year from 1971 through 2011. Figure 3 shows a scatter plot of the forecast errors. When we regress the forecast error for unemployment on the forecast error for output, the coefficient is -0.32 (standard error = 0.03), not too far from the Okun coefficients estimated by other methods.⁵ The \bar{R}^2 is 0.68 .

CBO Estimates

For completeness, we estimate Okun's Law one other way: we estimate the levels equation (3) with U_t^* and Y_t^* measured with estimates of the natural rate and potential output from the Congressional Budget Office. Economic commentators sometimes take this approach, and it produces a good fit. For the period 1980-2011, when the CBO series are available, the estimated Okun coefficient is -0.55 and the \bar{R}^2 is 0.89 . This \bar{R}^2 is higher than those from our other methods of estimating Okun's Law.

We should be cautious, however, in interpreting this result. The CBO's method for estimating U_t^* and Y_t^* uses a macro model that includes a version of Okun's Law as one assumption. Because U_t^* and Y_t^* are derived from Okun's Law, estimates based on these series are not independent evidence that Okun's Law holds.

C. Quarterly Data

Table 2a presents estimates of Okun's Law in levels and changes based on quarterly data. For the levels specification, we again estimate U_t^* and Y_t^* with the HP filter; we try smoothing parameters of $\lambda = 1,600$ and $\lambda = 16,000$, which are common choices for quarterly data. We present results with only the current output variable in the equation, and also with two lags included.

⁵ The equivalent regression for the same sample based on *actual* four-quarter changes in U_t and Y_t yields a coefficient estimate of -0.37 (standard error = 0.04).

For the levels specification with no lags, the estimated Okun coefficients are -0.43 and -0.41 , near the estimates with annual data. When lags are included, the coefficients on the current $Y_t - Y_t^*$ are smaller, and the two lags are significant, implying modest delays in the full adjustment of unemployment to output. The sums of the coefficients on current and lagged output are -0.49 and -0.45 . When the lags are included, the \bar{R}^2 s are a bit higher than those for annual data ($\bar{R}^2 = 0.87$ for $\lambda = 1,600$).

For the changes specification, the quarterly results are slightly less robust. With no lags, the coefficient on the change in output is only -0.29 ; when lags are included, the sum of coefficients is -0.43 , close to the results for the levels specification. The \bar{R}^2 is on the low side with no lags (0.49), and rises to 0.66 when lags are included. Evidently, the Okun relationship in quarterly changes is somewhat noisier than the levels relationship or the quarterly relationship in annual data.

We illustrate the fit of our levels specification by calculating fitted values for the unemployment rate. With lags included, these fitted values are

$$(5) \quad \hat{U}_t = U_t^* + \hat{\beta}_0(Y_t - Y_t^*) + \hat{\beta}_1(Y_{t-1} - Y_{t-1}^*) + \hat{\beta}_2(Y_{t-2} - Y_{t-2}^*),$$

where U_t^* and Y_t^* are long-run levels from the HP filter, and the $\hat{\beta}$ s are estimated coefficients on the current and lagged output gaps. In this exercise, we use a smoothing parameter of $\lambda = 1,600$ in the HP filter. Figure 4 compares the paths over time of \hat{U}_t and of actual unemployment U_t . We see that unemployment is close to the level predicted by Okun's Law throughout the period since 1948.

D. Comparison to Okun (1962)

We find that Okun's 50-year old specification fits our sample from 1948 through 2011. Yet our coefficient estimates differ somewhat from those in Okun's original paper. The absolute values of Okun's estimates are close to 0.3 ; inverting this coefficient, he posited the rule of thumb that a one point change in the unemployment rate occurs when output changes by three percent. Our coefficient estimates, by contrast, are around -0.4 or -0.5 . These estimates fit roughly with modern textbooks, which report an inverted coefficient of two.

Why do our coefficient estimates differ from Okun's? The natural guess is differences in data—either the sample period or the vintage of the data. But that is not the case; instead, the differences in results arise from differences in the specification of Okun's Law.

This point is easiest to see for the changes version of the Law. Okun estimates this specification, our equation (5), in quarterly data with no lags. Based on data for 1947Q2 through 1960Q4, he reports a coefficient of -0.30 . When we estimate the same equation for our sample, the coefficient is -0.29 (see the fifth column of Table 2b). For the changes equation, we obtain larger coefficients only if we use annual data or include lags in our quarterly specification.

To pin down this issue, Table 2b reports quarterly estimates of the changes equation with and without lags of output growth. We compare estimates for two periods: our full sample, and 1948Q2-1960Q4, which is our best approximation of Okun's sample with currently available data. For Okun's sample, we use 1965Q4 vintage data for output, which should be close to the data that Okun used.⁶ With no lags, the estimated coefficient is -0.31 for Okun's sample (column 1), compared with -0.29 for our full sample (column 5). When two lags are included, the sums of coefficients are, respectively, -0.44 and -0.43 (columns 2 and 6). Thus we confirm that lag structure rather than data differences explains the variation in results.

Since lags are significant when they are included, we interpret their absence from Okun's quarterly equation as a modest mis-specification. Okun underestimated the effects of output on unemployment because he assumed that they are fully contemporaneous at the quarterly frequency.

It is more difficult to compare our estimates of Okun's Law in levels to Okun's estimates, because of differences in the series for U^* and Y^* . Okun assumed that U^* is 4.0 percent (Okun, 1962, p. 3) even though unemployment averaged 4.6 over his sample, and he constructed a Y^* series that usually exceeds actual output. Our estimation of U^* and Y^* imposes the modern assumption that unemployment and output equal their long run levels on

⁶ The 1965Q4 vintage data is the earliest vintage of data for real GNP/GDP available from the Federal Reserve Bank of Philadelphia *Real-Time Data Set for Macroeconomists* (<http://www.philadelphiafed.org/research-and-data/real-time-center/real-time-data/data-files/ROUTPUT/>). The results are similar if we use the 1948Q2-1960Q4 sample and current (revised) data, as reported in columns (3)-(4) of Table 2b.

average. Presumably this issue, along with lag structure, helps explain why our levels results differ from Okun's.

E. Output, Employment, and Unemployment

We derived Okun's Law, equation (3), from underlying relationships between employment and output, and between unemployment and employment (equations (1) and (2)). To check the logic behind the Law, we now estimate the underlying relationships. We use annual data for 1948-2011 and estimate the long-run levels of all variables—employment as well as unemployment and output—with the HP filter and $\lambda = 100$. Also, when we estimate equations (1) and (2), we estimate them jointly with (3) as a system of seemingly unrelated regressions (SUR).

Table 3 presents the results. The estimate of coefficient γ in equation (1), which gives the effect of output on employment, is 0.54. Thus we confirm the prediction that this coefficient is smaller than 1.5 but greater in absolute value than the coefficient in Okun's Law (which is -0.41 for the levels specification with $\lambda = 100$). The estimate of coefficient δ in equation (2), which indicates the effect of employment on unemployment, is -0.73 , confirming the prediction that its absolute value is less than one. (As discussed in Section II, these predictions follow from costs of adjusting employment and procyclical labor force participation.) The estimate of coefficient β in equation (3) is -0.41 , as in our baseline specification reported in Table 1. The \bar{R}^2 s are 0.61 for equation (1), 0.80 for equation (2), and 0.82 for equation (3). Reassuringly, when we test the restriction that $\beta = \gamma\delta$, the p -value is 0.38.⁷ The scatterplots in Figure 5 confirm that the equations (1) and (2) fit well, with no major outliers.

IV. JOBLESS RECOVERIES?

Many observers suggest that Okun's Law has broken down in a particular way: recoveries following recessions have become "jobless," with weaker employment growth and

⁷ Given the non-linear nature of this restriction, we conduct the test using the delta method.

higher unemployment than Okun's Law predicts (for example, Gordon, 2011). The recoveries from the last three U.S. recessions—those of 1990-91, 2001, and 2008-2009—have all been called jobless. Many economists treat the emergence of jobless recoveries as a fact to be explained. In 2011, for example, Barcelona's Center for International Economic Research held a conference on "Understanding Jobless Recoveries" that focused on the three U.S. episodes.

We have found no evidence of a breakdown in Okun's Law. As Figure 3 shows, the path of U.S. unemployment consistently fits the predictions of Okun's Law, and recent recovery periods are no exception. This finding raises a puzzle: why do so many observers think that something in the employment-output relationship has changed?

To see why recent recoveries might appear jobless, we examine the recovery from the Great Recession of 2008-2009. Figure 6 shows the paths of output, unemployment, and the employment-population ratio from 2007 through 2011. We also present estimates of the long-run levels of the three variables based on their pre-recession behavior. As in Figure 2, we estimate trends with the HP filter through 2007, and assume that U_t^* , the growth of Y_t^* , and the growth of the long-run employment-population ratio remain at their 2007 levels over 2008-2013.

Many interpret the experience shown in Figure 6 as a jobless recovery. For example, the website of National Public Radio (2011) presents similar graphs under the headline, "Output Came Back, Employment Didn't." These statements are true in the sense that the employment-population ratio has been steady at a low level, while the growth rate of output has returned to normal (the paths of actual and potential output are roughly parallel) and the level of output surpassed its pre-recession peak in 2011.

Yet, as the Figure makes clear, Okun's Law has not broken down. Okun's Law is a relationship between deviations of unemployment and output from their long-run levels. Since a large output gap has persisted, Okun's Law predicts large deviations of employment and unemployment from their long-run levels. From 2009 through 2011, the output gap as measured in Figure 6 averaged -10.8 percent and the unemployment gap averaged 4.4 percentage points. The ratio of the two gaps, -0.41, is close to our earlier estimates of the Okun coefficient.

Why have the last three recoveries been viewed as jobless, while previous recoveries

were not? Gali et al. (2012) give the answer: since the 1990s, the speed of recoveries (which they measure with output growth in the three years after a trough) has been slower than before. In the early 1990s and early 2000s, as well as after the Great Recession, slow growth meant that sizable output gaps persisted well into the recovery. In contrast, in most earlier recessions, the output trough was followed by a period of above-normal growth that pulled output back to its previous trend. As Okun's Law predicts, employment and unemployment also returned to normal, and that made the recoveries look job-full.

Figure 7 illustrates this point with data for the early 1980s. After the recession of 1981-82, output growth averaged 5.9 percent over 1983-84, with the result that output, employment, and unemployment were all close to their previous trends by 1984. Based on experiences like this one, observers came to expect that the end of a recession would lead quickly to a full recovery of employment. They were surprised when this did not happen more recently, even though Okun's Law has not changed.

To be clear, we explain the behavior of employment in recent recoveries taking as given the fact that output growth was slow. Gali et al. (2012) discuss possible explanations for slow growth, such as the zero bound that has constrained monetary policy since 2008.

V. OKUN'S LAW IN 20 ADVANCED ECONOMIES

Here we examine the fit of Okun's Law in 20 countries: those with populations above one million that were members of the OECD in 1985. We use annual data on output and unemployment from the OECD.⁸

A. Basic Results

We examine the period from 1980-2011 (except for Ireland, where the data start in 1990). We start our samples in 1980 because, in a number of countries, unemployment was very low in earlier periods. An extreme example is New Zealand, where unemployment rates

⁸ We present results for OECD data based on national definitions of unemployment. The results are similar when we use the OECD's harmonized unemployment series.

between 1960 and 1975 ranged from 0.04 percent to 0.66 percent. Evidently, some countries' economic regimes in the 60s and 70s differed from those of more recent decades, or unemployment was measured differently.

For each country in our sample, Table 4 reports estimates of Okun's Law in levels, with U_t^* and Y_t^* measured with an HP parameter of $\lambda = 100$. The fit is good for most countries, though usually not as close as for the United States. The \bar{R}^2 exceeds 0.4 in all countries but Austria and Italy. Spain's \bar{R}^2 of 0.90 is the highest.⁹

The estimated coefficients on the output gap vary across countries. Most are spread between -0.23 and -0.54 , but two are lower in absolute value (Austria and Japan), and Spain is an outlier with -0.85 . Countries with higher \bar{R}^2 s generally have higher coefficients, although Japan is an exception: it has a fairly high \bar{R}^2 (0.74) but a low coefficient (-0.16). Japan's unemployment movements are small and are well explained by its output movements and a low coefficient in Okun's Law.

We have also estimated Okun's Law with an HP parameter of $\lambda = 1,000$ for U_t^* and Y_t^* , and Okun's Law in changes. The results are qualitatively similar to those in Table 4, although the fit is not as close for some countries. Averaging across the 20 countries, the \bar{R}^2 is 0.63 for the $\lambda = 100$ results in Table 4, 0.59 for $\lambda = 1,000$, and 0.49 for the changes equation. The average coefficients for the three specifications are -0.40 , -0.37 , and -0.33 .

B. Stability Over Time

We now ask whether the Okun's Law coefficient is stable over time in a given country. Previous studies have suggested not: Cazes et al. (2012) find that the coefficient varies erratically in many countries, and IMF (2010) finds that it has generally risen over time. The IMF study's explanation is that legal reforms have reduced the costs of firing workers.

As with the United States, we do a simple check for stability in each country by estimating separate coefficients for the first and second halves of the sample: 1980-1995 and

⁹ We estimate the Okun coefficient for each country with OLS. The results are similar if we estimate the coefficients jointly in a panel framework with Seemingly Unrelated Regressions (SUR).

1996-2011. Table 5 presents the results.

We find some evidence of instability: for seven of the 20 countries, we can reject equality of the first-half and second-half coefficients at the five percent level. However, in five out of these seven cases, the coefficient is *lower* in absolute value in the second half of the sample. The average coefficient for the 20 countries is -0.43 in the first half of the sample and -0.36 in the second. Our data generally do not support the view that the Okun coefficient has risen over time.

The differences in coefficients across countries are similar in the two time periods. For example, Spain's coefficient is the highest in both periods, and Austria and Japan's are the two lowest. Overall, the correlation of coefficients across the two periods is 0.49.

VI. OKUN'S LAW IN THE GREAT RECESSION

Skepticism about Okun's Law has grown in the wake of the Great Recession of 2008-2009. One reason, emphasized by IMF (2010) and McKinsey (2011), is that there is little correlation across countries between decreases in output and increases in unemployment during the countries' recessions. Once again, we believe that claims of a breakdown in Okun's Law are exaggerated.

A. Output and Unemployment from Peak to Trough

We can see why a quick look at the data might suggest a breakdown of Okun's Law. Nineteen of the countries in our sample (all but Australia) experienced a recession that began in either late 2007 or 2008, according to Harding and Pagan's (2002) definitions of peaks and troughs in output. For these countries, Figure 8a plots the change in output from peak to trough against the change in unemployment over the same period. This Figure is similar to one in IMF (2010).

The Figure shows that changes in output and unemployment are uncorrelated across countries. When the change in U is regressed on a constant and the change in Y , the \bar{R}^2 is -0.03 . Commentators have used subsets of the observations in Figure 8a as evidence against Okun's Law. McKinsey, for example, points out that Germany and the United Kingdom had

larger output falls than the United States and Spain, yet unemployment increased by less in the U.K. and fell in Germany.

Such evidence has led researchers to propose novel factors to explain unemployment changes. IMF (2010) suggests that financial crises and house price busts raise unemployment for a given level of output. McKinsey suggests that output growth may fail to decrease unemployment because workers lack the skills for available jobs.

B. Correcting for the Length of Recessions

It is misleading to compare output and unemployment changes during different countries' recessions, because recessions last for varying lengths of time. For the set of recessions in Figure 8a, the period from peak to trough ranges from two quarters in Portugal to seven quarters in Demark. Okun's Law implies a relationship between the changes in unemployment and output only if we control for this factor.

To see this point, suppose that the changes version of Okun's Law holds exactly in quarterly data:

$$(6) \quad \Delta U_t = \alpha + \beta \Delta Y_t, \alpha > 0, \beta < 0,$$

where for the moment we assume the parameters α and β are the same for all countries. Let T be the number of quarters in a recession. Cumulating equation (6) over T quarters gives

$$(7) \quad \Sigma \Delta U = \alpha T + \beta \Sigma \Delta Y,$$

where Σ indicates the cumulative change over a recession.

Recall that $\alpha > 0$ because potential output grows over time. Thus, holding constant the change in output, a longer recession implies a larger rise in unemployment. With potential output on an upward path, a given absolute fall in output translates into a larger output gap and higher unemployment if it occurs over a longer period

We examine the fit of equation (7) across countries by regressing the change in U during a country's recession on the change in Y and the recession length T (without a constant term). This regression yields estimates of $\alpha = 0.70$ (standard error = 0.30) and

$\beta = -0.12$ (standard error = 0.25). Figure 8b plots the cumulative change in the unemployment rate, $\Sigma \Delta U$, against the fitted values from this regression. We see that the version of Okun's Law in equation (7) explains a substantial part of the cross-country variation in ΔU : the \bar{R}^2 is 0.54. Notice that Spain is less of an outlier than it was in Figure 8a. The large increase in Spanish unemployment is partly explained by the length of Spain's recession—six quarters, the second-longest in the sample.

C. Adjusting for Country-Specific Coefficients

We saw in Section V that the coefficient in Okun's Law varies substantially across countries. We now ask whether changes in unemployment during the Great Recession fit the Law, given the usual coefficient for each country. That is, we examine the fit of

$$(8) \quad \Sigma \Delta U = \alpha_i T + \beta_i \Sigma \Delta Y,$$

where α_i and β_i are the parameters of Okun's Law for country i .

We compute the fitted values of $\Sigma \Delta U$ implied by equation (8). For α_i and β_i , we use estimates of Okun's Law in changes for annual data over 1980-2011 (with α_i divided by four to fit the current exercise with quarterly data). The α_i 's average 0.87 across countries (0.22 once we divide by four), and the β_i 's are highly correlated with the Okun coefficients in Table 4 (which are estimated with the levels version of Okun's Law).

Figure 8c shows the results. Here, the fitted values of $\Sigma \Delta U$ do a good job of explaining the actual values of $\Sigma \Delta U$: the \bar{R}^2 is 0.76. Again, Spain is a good example. Its large rise in unemployment is explained almost entirely by the fact that its Okun coefficient β_i is unusually large, along with the length of its recession. In other words, Spain *did* experience a larger rise in unemployment than other countries, but that is what we should expect based on its historical Okun's Law.

D. A German Miracle?

When economists discuss deviations from Okun's Law, many stress the recent experience of Germany. As Figure 8 shows, Germany is the one country where

unemployment fell during its recession, an outcome that is often called a “miracle” (for example, Burda and Hunt, 2011). Many economists explain this experience with work-sharing—decreases in hours per worker—encouraged by government subsidies to employers who retained workers.

Figure 8c confirms that Germany deviated from Okun’s Law during its recession. Its predicted change in unemployment was 2.22 percentage points, and its actual change was -0.26 percentage points. This episode reminds us that Okun’s Law does not explain 100 percent of unemployment behavior. Yet “miracle” may be an exaggeration of Germany’s experience. The residual in Germany’s Okun’s Law is modest compared to cross-country differences in unemployment changes.

VII. EXPLAINING CROSS-COUNTRY VARIATION IN OKUN’S LAW

We have seen that most countries have a well-fitting Okun relationship, but that the Okun coefficient differs across countries. What explains these differences?

A. Looking for Explanatory Variables

We can gain some insight about the Okun coefficient from Figure 9, which plots the estimated coefficients for our 20 countries against the average level of unemployment over 1980-2011 (top-left panel). We see an inverse relationship: in countries where unemployment is higher on average, it also fluctuates more in response to output movements. This result is driven primarily by a cluster of countries with low unemployment and low coefficients—Switzerland, Japan, Austria, and Norway—and by Spain, which has very high unemployment and a very high coefficient. It appears likely that the underlying factors that determine the Okun coefficient also influence average unemployment.

We have looked for the underlying determinants of the Okun coefficient, but our results are largely negative. A notable failure is the OECD’s well-known index of employment protection legislation (EPL). In theory, greater employment protection should dampen the effects of output movements on employment and therefore reduce the Okun coefficient. In Figure 9 (top-right panel), we test this idea by plotting the coefficient against

the OECD's overall EPL index (averaged over 1985-2008, the period for which it is available).¹⁰ The relationship between the two variables has the wrong sign, and it is statistically insignificant. Similarly, we find no relationship between the Okun coefficient and two other plausible explanatory factors: the share of youth unemployment in total unemployment and the share of long-term unemployment in total unemployment (Figure 9, lower row). For these two variables, relationship with the Okun coefficient is statistically insignificant.¹¹

B. Individual Countries

We can also learn about the Okun coefficient by examining individual countries. It appears that the labor markets of many countries have idiosyncratic features that influence the coefficient. These features—not one or two variables that we can measure for all countries—probably account for most of the variation in the coefficient. To support this idea, we examine the country with the highest estimated coefficient, Spain, and the three countries with the lowest coefficients.

Spain

This country's Okun coefficient, -0.85 , is much higher in absolute value than any other country's. The natural explanation is the unusually high incidence of temporary employment contracts. Labor market reforms in the 1980s made it easier for Spanish employers to hire workers on fixed-term contracts, without the employment protection guaranteed to permanent workers. Over the 1990s and 2000s, such contracts have accounted for around a third of Spanish employment. Temporary contracts make it easier for firms to adjust employment when output changes, raising the Okun coefficient.

¹⁰ For New Zealand, the EPL index is available over 1990-2008. We also find no evidence of a relationship between the Okun coefficient and the EPL index sub-components.

¹¹ Some preliminary results suggest that the share of youth in the total labor force or the ratio of youth to older people in the labor force has a stronger relationship with the Okun coefficient. Similarly, there appears to be a positive relationship between the aggregate Okun coefficient and the Okun coefficient estimated for youth. We plan to report on these findings in the revised draft of this paper.

Notice that the OECD's EPL index assigns a fairly high number to Spain, suggesting that it is *not* easy for Spanish employers to adjust employment. However, close observers of Spain argue that the OECD index is not a good measure of flexibility in this case. One reason is that the OECD does not account for the non-enforcement of *de jure* restrictions on fixed-term contracts (Bentolila et al., 2010).

Japan

This country's Okun coefficient, -0.16 , is the second smallest in absolute value. The likely explanation is Japan's tradition of "lifetime employment," which makes firms reluctant to lay off workers. This feature of the labor market is a choice of employers, not a legal mandate, and therefore is not captured by the EPL index.

Ono (2010) reports that the lifetime employment tradition has weakened somewhat over time. This suggests that Japan's Okun coefficient may have risen—and indeed, Japan is one of the two countries with a statistically significant increase in the coefficient from the first half of our sample period to the second (see Table 5). However, the coefficient is low compared to other countries—under 0.2—in both parts of the sample.

Switzerland

This country's coefficient, -0.24 , is the third smallest. A likely explanation is the large use of foreign workers in Switzerland. When employment rises or falls, migrant workers move in and out of the country. Changes in employment are accommodated by changes in the labor force, and unemployment is stable.

Recall that Okun's Law is derived from an employment-output relationship, equation (1), and an unemployment-employment relationship, equation (2). We estimate these two equations for our 20 countries and examine where Switzerland lies in the ranges of coefficients. Switzerland's coefficient in the E - Y equation, 0.46 , is near the middle of the range for the 20 countries. Switzerland's coefficient in the U - E equation, -0.17 , is the second smallest, and it is statistically insignificant. These results confirm that Switzerland's unusual feature is the non-responsiveness of unemployment to employment.

Austria

Austria's Okun coefficient, -0.14 , is the smallest for our 20 countries. We have not found an explanation for this result. When we estimate the E - Y and U - E relationships for Austria, the coefficients in both are implausibly small—less than 0.02 in absolute value.

VIII. CONCLUSION

It is rare to call a macroeconomic relationship a “law.” Yet we believe that Okun's Law has earned its name. It is not as universal as the law of gravity (which has the same parameters in all advanced economies), but it is strong and stable by the standards of macroeconomics. Reports of deviations from the Law are often exaggerated. Okun's Law is certainly more reliable than a typical macro relationship like the Phillips curve, which is constantly under repair as new anomalies arise in the data.

The evidence in this paper is consistent with traditional macro models in which shifts in aggregate demand cause short run fluctuations in unemployment. At this point, we do not claim that the evidence is *not* consistent with other theories of unemployment, such as those based on sectoral shocks or extensions of unemployment benefits. The usefulness of Okun's Law in testing macro theories is a topic for future research.

A possible starting point is the fact that the Okun coefficient is far smaller than one would expect from an inverted production function (even when we put employment rather than unemployment on the left side of the Law). Traditional macro explains this fact with costs of adjusting employment to aggregate demand shifts. It is not clear whether a small Okun's coefficient arises naturally in other models of unemployment.

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Table 1. United States: Estimates of Okun's Law

(Annual data, 1948-2011)

Equation estimated in levels: $U_t - U_t^* = \beta (Y_t - Y_t^*) + \varepsilon_t$ Equation estimated in first differences: $\Delta U_t = \alpha + \beta \Delta Y_t + \varepsilon_t$

Equation in levels	
Hodrick-Prescott filter $\lambda = 100$	
β	-0.411*** (0.024)
<i>Obs</i>	64
Adjusted R^2	0.817
RMSE	0.426
Hodrick-Prescott filter $\lambda = 1,000$	
β	-0.383*** (0.023)
<i>Obs</i>	64
Adjusted R^2	0.813
RMSE	0.524
Equation in first differences	
β	-0.405*** (0.029)
α	1.349*** (0.116)
<i>Obs</i>	63
Adjusted R^2	0.752
RMSE	0.556

Note: Table reports point estimates and standard errors in parentheses. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent level.

Table 2a. United States: Estimates of Okun's Law

(Quarterly data, 1948Q2-2011Q4)

Equation estimated in levels: $U_t - U_t^* = \beta(L) (Y_t - Y_t^*) + \varepsilon_t$ Equation estimated in first differences: $\Delta U_t = \alpha + \beta(L) \Delta Y_t + \varepsilon_t$

	Equation in levels Hodrick-Prescott filter λ				Equation in first differences	
	1,600	1,600	16,000	16,000		
β_0	-0.428*** (0.015)	-0.245*** (0.0230)	-0.411*** (0.013)	-0.213*** (0.0286)	-0.286*** (0.018)	-0.218*** (0.0160)
β_1		-0.133*** (0.0345)		-0.153*** (0.0447)		-0.137*** (0.0168)
β_2		-0.116*** (0.0230)		-0.0794*** (0.0286)		-0.0767*** (0.0160)
$\beta_0 + \beta_1 + \beta_2$		-0.494*** (0.0126)		-0.445*** (0.0119)		-0.432*** (0.0200)
α						0.359*** (0.0215)
<i>Obs</i>	256	256	256	256	255	255
Adjusted R^2	0.767	0.865	0.795	0.852	0.494	0.663
RMSE	0.398	0.302	0.463	0.394	0.287	0.234

Note: Table reports point estimates and standard errors in parentheses. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent level.

Table 2b. United States: Replication and Update of Okun's (1962) Regression
(Quarterly data)

Equation estimated: $\Delta U_t = \alpha + \beta(L) \Delta Y_t + \varepsilon_t$

Sample Data	1948Q2-1960Q4 Vintage data		1948Q2-1960Q4 Current data		1948Q2-2011Q4 Current data	
Column	(1)	(2)	(3)	(4)	(5)	(6)
β_0	-0.307*** (0.036)	-0.233*** (0.0303)	-0.323*** (0.038)	-0.250*** (0.0313)	-0.286*** (0.018)	-0.218*** (0.0160)
β_1		-0.168*** (0.0327)		-0.160*** (0.0346)		-0.137*** (0.0168)
β_2		-0.0394 (0.0307)		-0.0631* (0.0320)		-0.0767*** (0.0160)
$\beta_0 + \beta_1 + \beta_2$		-0.441*** (0.0380)		-0.473*** (0.0395)		-0.432*** (0.0200)
α	0.305*** (0.061)	0.424*** (0.0524)	0.323*** (0.062)	0.464*** (0.0535)	0.244*** (0.023)	0.359*** (0.0215)
<i>Obs</i>	51	51	51	51	255	255
Adjusted R^2	0.584	0.758	0.592	0.764	0.494	0.663
RMSE	0.382	0.292	0.378	0.288	0.287	0.234

Note: Table reports point estimates and standard errors in parentheses. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent level.

Table 3. United States: Estimates of Okun's Law and Unemployment-Employment Relation
(Annual data, 1948-2011)

Equations estimated jointly:

$$(1) \quad E_t - E_t^* = \gamma (Y_t - Y_t^*) + \eta_t$$

$$(2) \quad U_t - U_t^* = \delta (E_t - E_t^*) + \mu_t$$

$$(3) \quad U_t - U_t^* = \beta (Y_t - Y_t^*) + \varepsilon_t$$

Okun's Law for Employment

γ	0.543*** (0.040)
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<i>Obs</i>	64
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Adjusted R^2	0.610
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Unemployment-Employment Relation

δ	-0.728*** (0.027)
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<i>Obs</i>	64
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Adjusted R^2	0.798
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Okun's Law for Unemployment

β	-0.405*** (0.024)
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<i>Obs</i>	64
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Adjusted R^2	0.820
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p -value for $H_0: \beta = \gamma\delta$	0.378
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Note: Table reports estimation results for seemingly unrelated regressions (SUR) model comprising equations (1)-(3), with standard errors in parentheses. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent level. E denotes log of employment. Natural rates (E_t^* , Y_t^* , and U_t^*) based on Hodrick-Prescott filter with $\lambda = 100$.

Table 4. 20 Advanced Economies: Estimates of Okun's Law
(Annual data, 1980-2011)

Equation estimated: $U_t - U_t^* = \beta (Y_t - Y_t^*) + \varepsilon_t$

	β	<i>Obs</i>	Adjusted R^2	RMSE
Australia	-0.536*** (0.0476)	32	0.797	0.439
Austria	-0.136*** (0.0438)	32	0.213	0.375
Belgium	-0.511*** (0.0817)	32	0.543	0.708
Canada	-0.432*** (0.0374)	32	0.805	0.495
Denmark	-0.434*** (0.0471)	32	0.724	0.570
Finland	-0.504*** (0.0485)	32	0.770	1.025
France	-0.367*** (0.0441)	32	0.681	0.394
Germany	-0.367*** (0.0629)	32	0.508	0.689
Ireland	-0.406*** (0.0395)	32	0.766	0.835
Italy	-0.254*** (0.0672)	32	0.292	0.654
Japan	-0.152*** (0.0194)	32	0.654	0.229
Netherlands	-0.511*** (0.0705)	32	0.617	0.722
New Zealand	-0.341*** (0.0493)	32	0.594	0.705
Norway	-0.294*** (0.0406)	32	0.617	0.449
Portugal	-0.268*** (0.0371)	32	0.615	0.629
Spain	-0.852*** (0.0503)	32	0.899	0.757
Sweden	-0.524*** (0.0719)	32	0.619	1.002
Switzerland	-0.234*** (0.0458)	32	0.439	0.434
United Kingdom	-0.343*** (0.0495)	32	0.595	0.699
United States	-0.454*** (0.0373)	32	0.821	0.418

Note: Natural rates (U_t^* and Y_t^*) based on Hodrick-Prescott filter with $\lambda = 100$. Table reports point estimates and standard errors in parentheses. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent level.

Table 5. 20 Advanced Economies: Estimates of Okun's Law
(Annual data, 1980-2011)

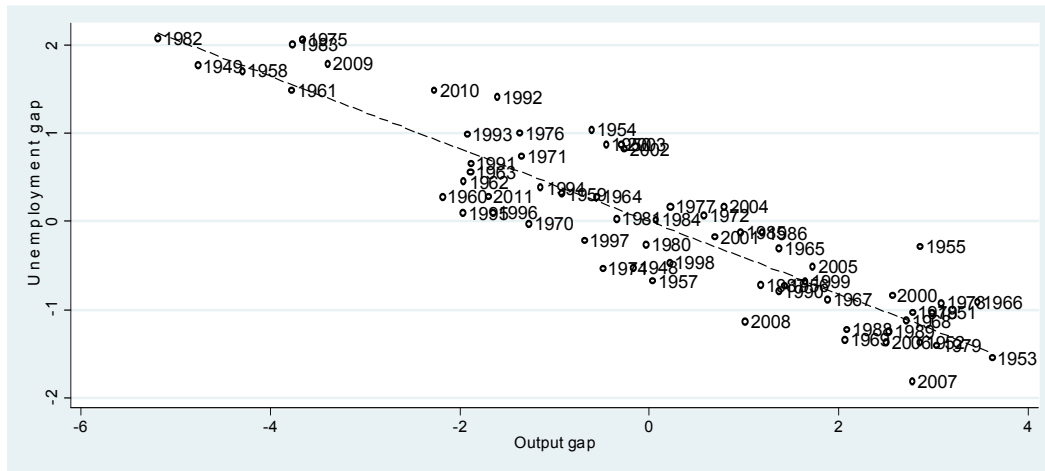
Equation estimated: $U_t - U_t^* = \beta_{\text{pre-95}} (Y_t - Y_t^*) + \beta_{\text{post-95}} (Y_t - Y_t^*) + \varepsilon_t$

	$\beta_{\text{pre-95}}$		$\beta_{\text{post-95}}$		p -value	Obs	Adjusted R^2	RMSE
Australia	-0.552***	(0.051)	-0.433***	(0.131)	0.405	32	0.796	0.441
Austria	-0.134*	(0.068)	-0.137**	(0.0587)	0.974	32	0.187	0.382
Belgium	-0.634***	(0.099)	-0.310**	(0.126)	0.053	32	0.584	0.676
Canada	-0.500***	(0.041)	-0.287***	(0.059)	0.006	32	0.844	0.442
Denmark	-0.490***	(0.064)	-0.369***	(0.068)	0.205	32	0.730	0.564
Finland	-0.610***	(0.051)	-0.297***	(0.071)	0.001	32	0.833	0.872
France	-0.400***	(0.063)	-0.335***	(0.063)	0.470	32	0.676	0.397
Germany	-0.427***	(0.079)	-0.270**	(0.102)	0.232	32	0.516	0.684
Ireland	-0.462***	(0.073)	-0.382***	(0.047)	0.359	32	0.765	0.836
Italy	-0.142	(0.094)	-0.358***	(0.091)	0.110	32	0.330	0.637
Japan	-0.109***	(0.023)	-0.209***	(0.027)	0.008	32	0.718	0.206
Netherlands	-0.713***	(0.092)	-0.336***	(0.086)	0.006	32	0.695	0.645
New Zealand	-0.317***	(0.056)	-0.426***	(0.104)	0.363	32	0.592	0.707
Norway	-0.319***	(0.050)	-0.247***	(0.07)	0.410	32	0.613	0.451
Portugal	-0.221***	(0.037)	-0.463***	(0.0755)	0.007	32	0.688	0.567
Spain	-0.793***	(0.067)	-0.923***	(0.074)	0.205	32	0.902	0.749
Sweden	-0.648***	(0.091)	-0.362***	(0.104)	0.046	32	0.656	0.953
Switzerland	-0.211***	(0.058)	-0.274***	(0.077)	0.516	32	0.429	0.439
United Kingdom	-0.419***	(0.059)	-0.215***	(0.077)	0.045	32	0.635	0.663
United States	-0.447***	(0.050)	-0.464***	(0.058)	0.829	32	0.815	0.425

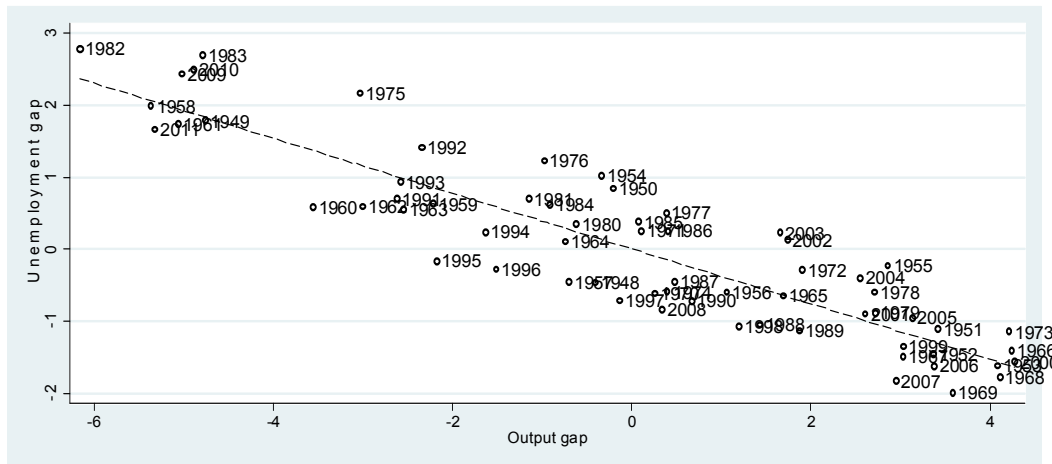
Notes: Natural rates (U_t^* and Y_t^*) based on Hodrick-Prescott filter with $\lambda = 100$. $\beta_{\text{pre-95}}$ denotes 1980-1994 sample; $\beta_{\text{post-95}}$ denotes 1995-2011 sample. Table reports point estimates and standard errors in parentheses, and p -value for test of equality of coefficients across the two sub-samples. ***, **, and * indicate statistical significance at the 1, 5, and 10 percent level.

Figure 1a. United States: Okun's Law, 1948-2011
(Annual data)

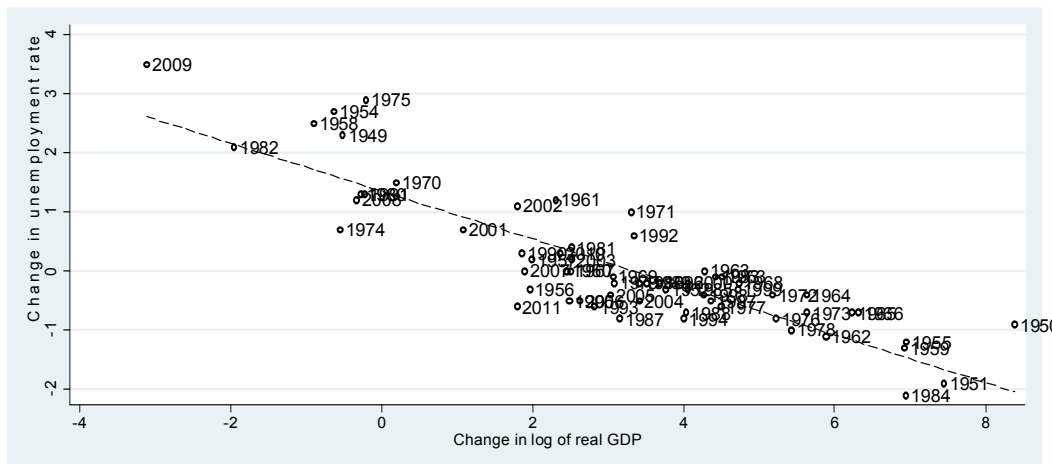
1. Levels: Natural Rates Based on HPF with $\lambda = 100$



2. Levels: Natural Rates Based on HPF with $\lambda = 1,000$

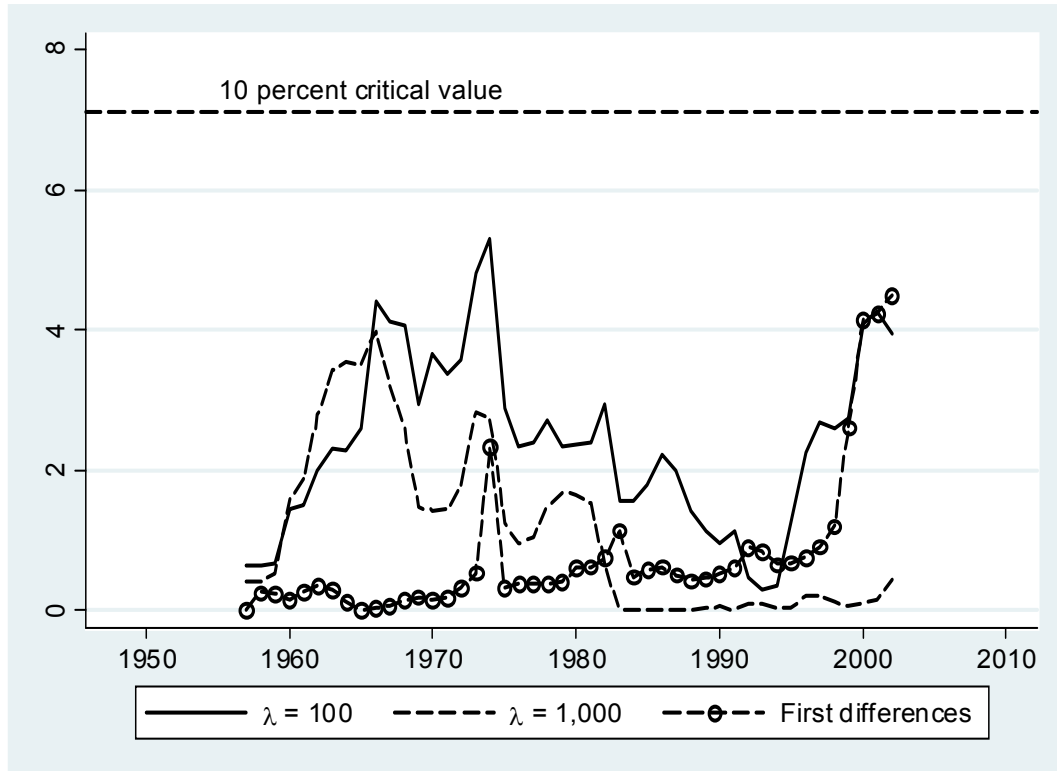


3. First Differences



Notes: HPF denotes Hodrick-Prescott filter. Figure reports change in unemployment rate and in log of real GDP in percentage points, and output gap and unemployment gap in percent.

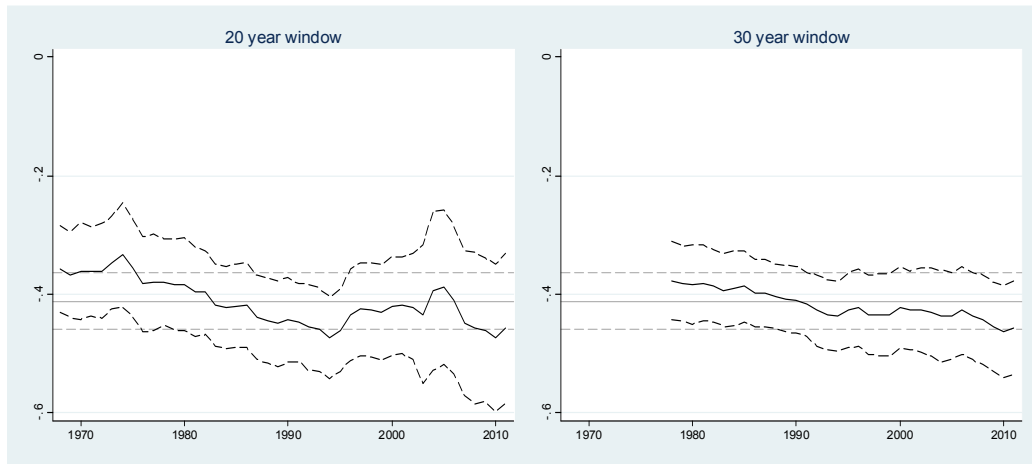
Figure 1b. United States: Test for Okun Coefficient Instability at Unknown Date, 1948-2011 (Annual data)



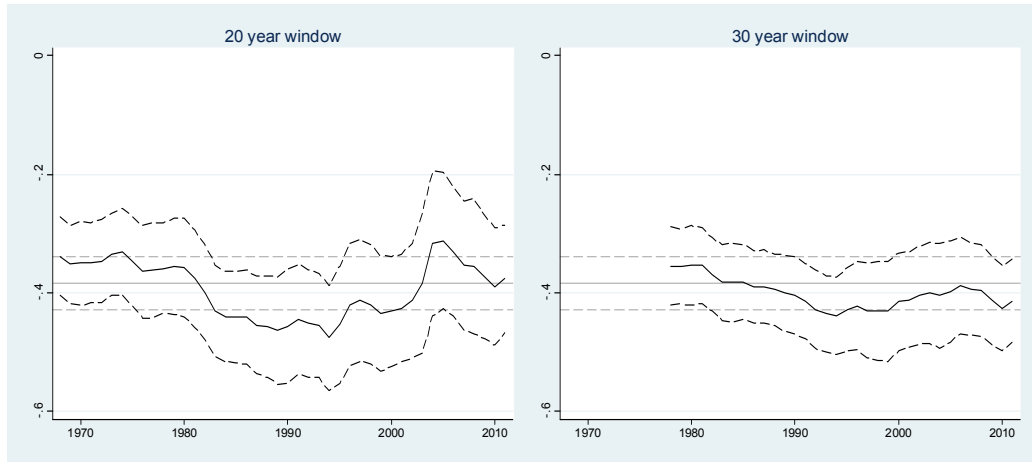
Notes: Figure reports F statistic for break in Okun coefficient (β) for each date in the conventional inner 70 percent of the sample (excluding the first and last 15 percent of observations). Critical value for rejection of null of parameter stability taken from Andrews (2003).

Figure 1c. United States: Rolling Regressions for Okun's Law, 1948-2011 (Annual data)
(Estimates and 95-confidence bands)

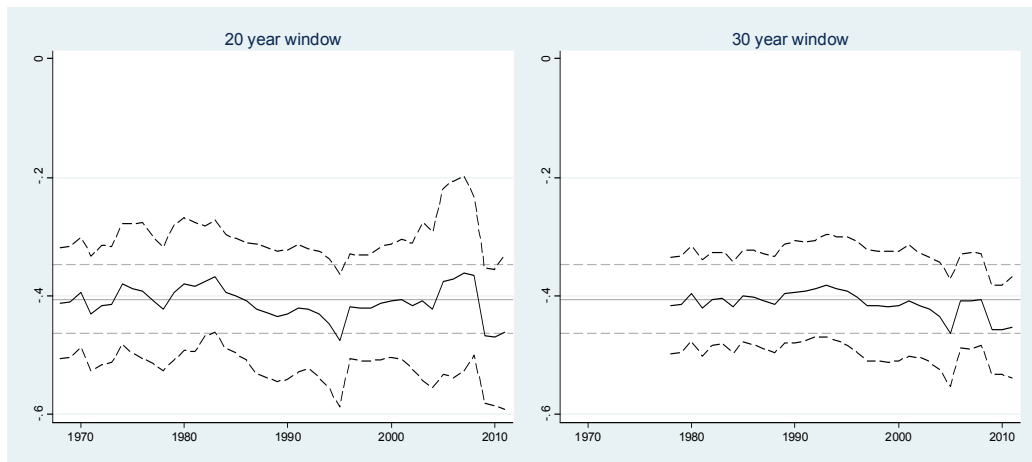
1. Levels: Natural Rates Based on HPF with $\lambda = 100$



2. Levels: Natural Rates Based on HPF with $\lambda = 1,000$



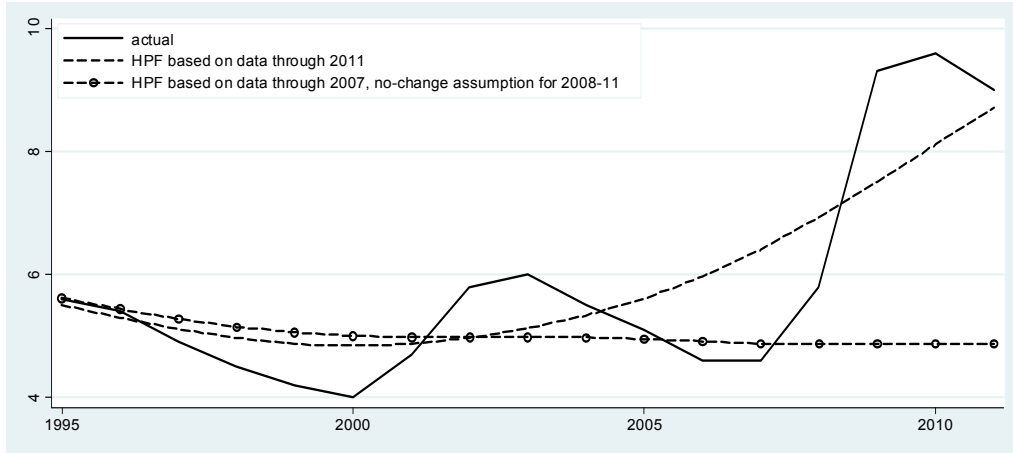
3. First Differences



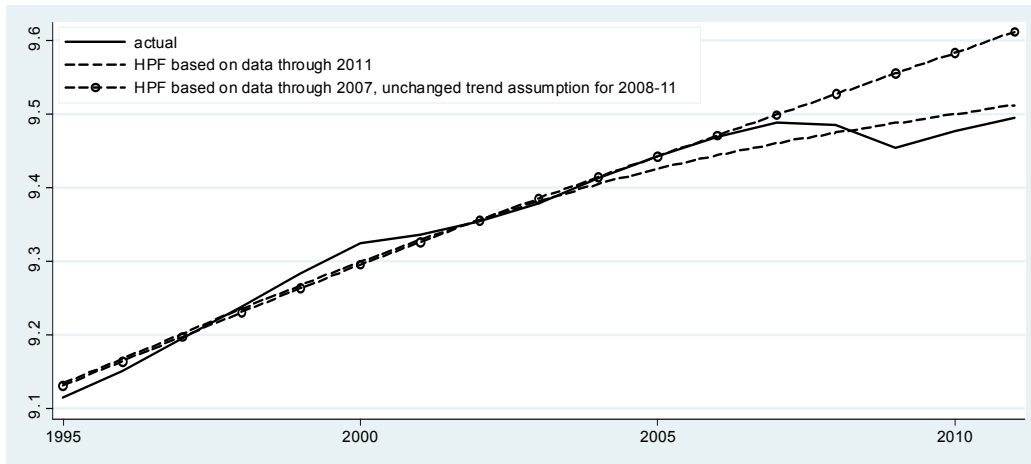
Notes: Figure reports rolling regression coefficient and 95-percent confidence interval for end of regression window. Light-colored lines indicate baseline constant Okun coefficient estimate and 95-percent confidence interval.

Figure 2. Robustness: U.S. Natural Rates

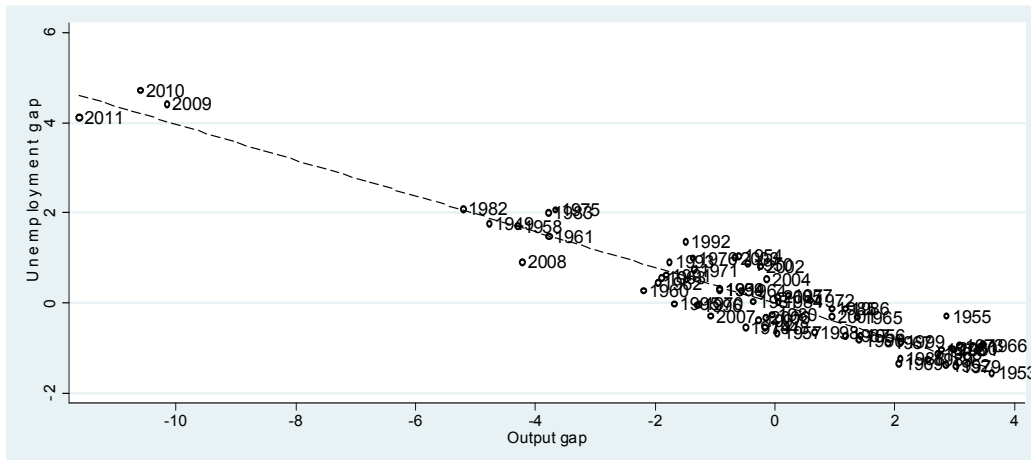
a. Unemployment Rate: Actual and Natural



b. Output: Actual and Natural

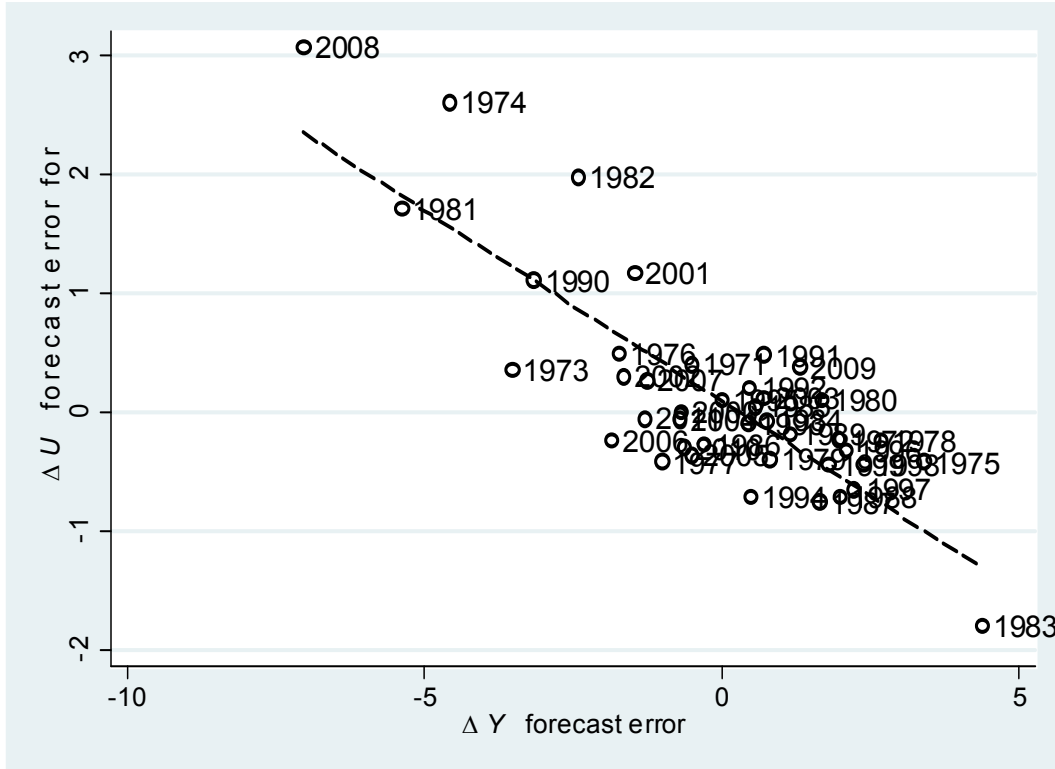


c. HPF based on Data through 2007, No Change Assumption for 2008-11



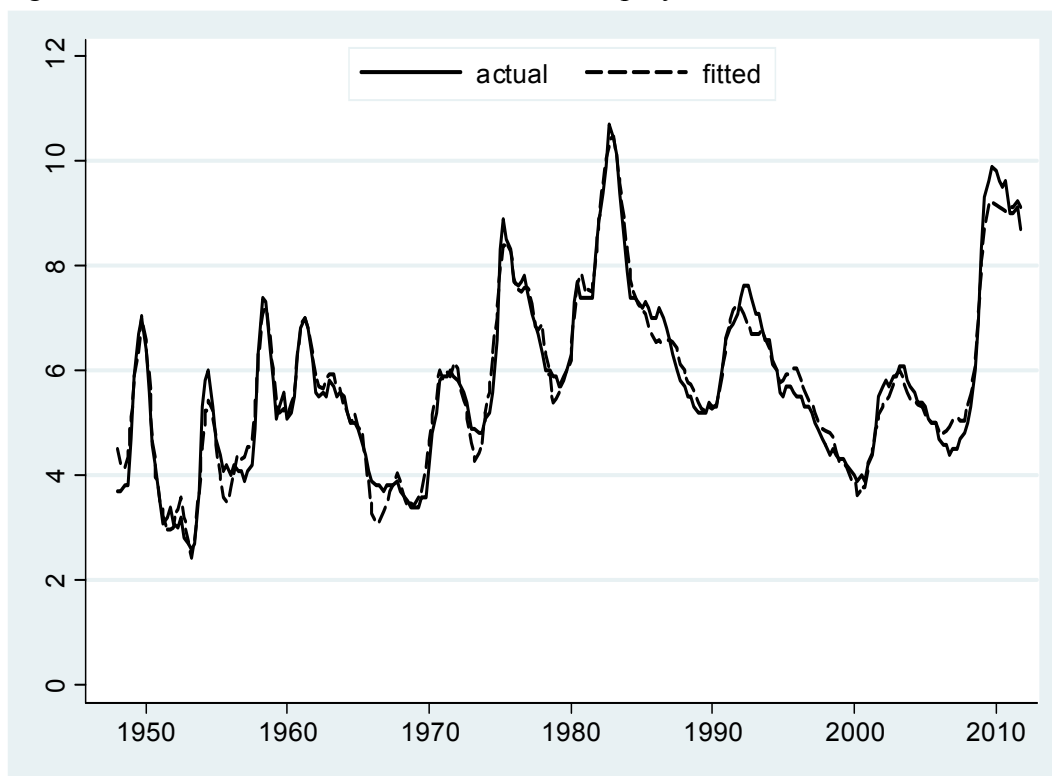
Note: HPF denotes Hodrick-Prescott filter with $\lambda = 100$.

Figure 3. United States: Okun's Law Based on Forecast Errors
 (Forecast errors for four-quarter-ahead forecasts of four-quarter changes, 1971Q1-2011Q1)



Note: Figure reports forecast errors based on forecasts published in the first quarter of each year in the Survey of Professional Forecasters.

Figure 4. United States: Actual and Fitted Unemployment Rate, 1948Q2-2011Q4

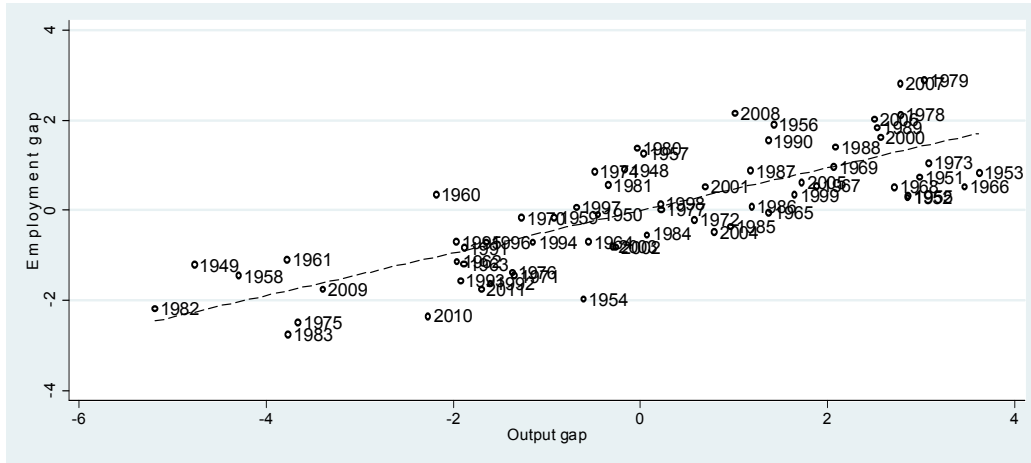


Notes: Figure reports fitted unemployment rate from Okun specification estimated on quarterly data in levels with two lags and natural rates based on Hodrick-Prescott filter with $\lambda = 100$.

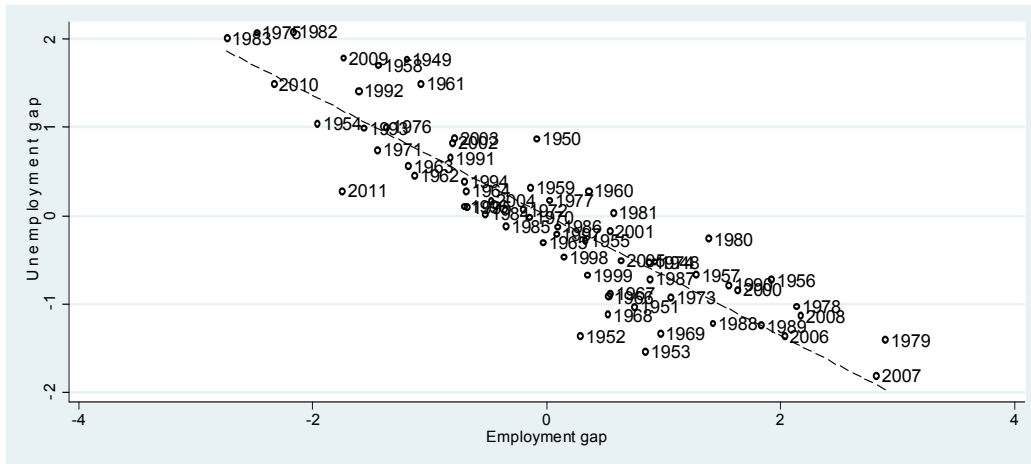
Figure 5. United States: Okun's Law for Employment, and Unemployment-Employment Relation, 1948-2011

(Annual data, natural rates based on HPF with $\lambda = 100$)

a. Okun's Law for Employment

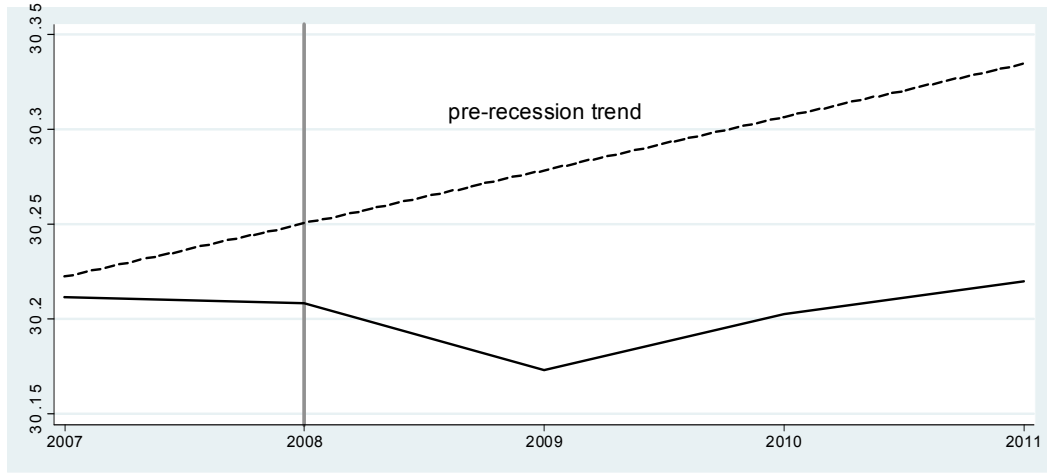


b. Unemployment-Employment Relation

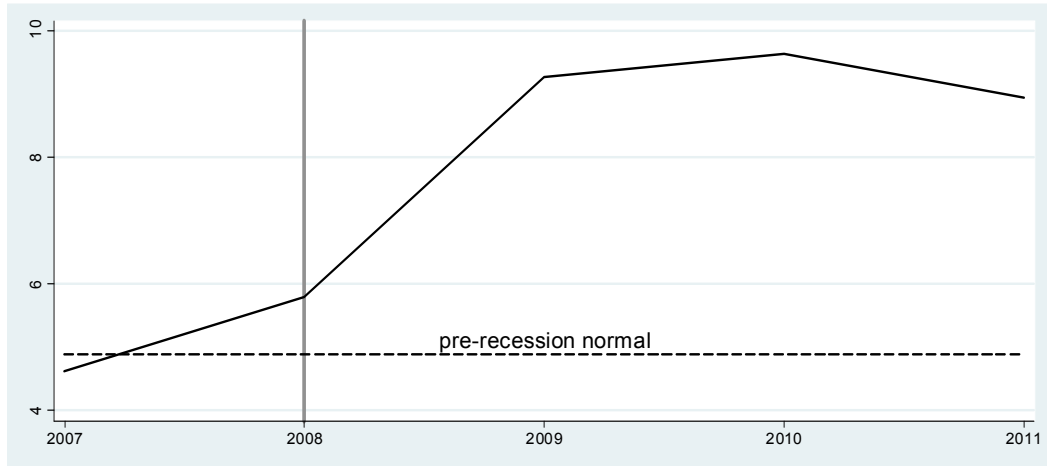


Notes: Figure reports all variables in percentage points. HPF denotes Hodrick-Prescott filter.

Figure 6. United States and the Great Recession
a. Log of Real GDP



b. Unemployment Rate



c. Log of Employment-to-Population Ratio

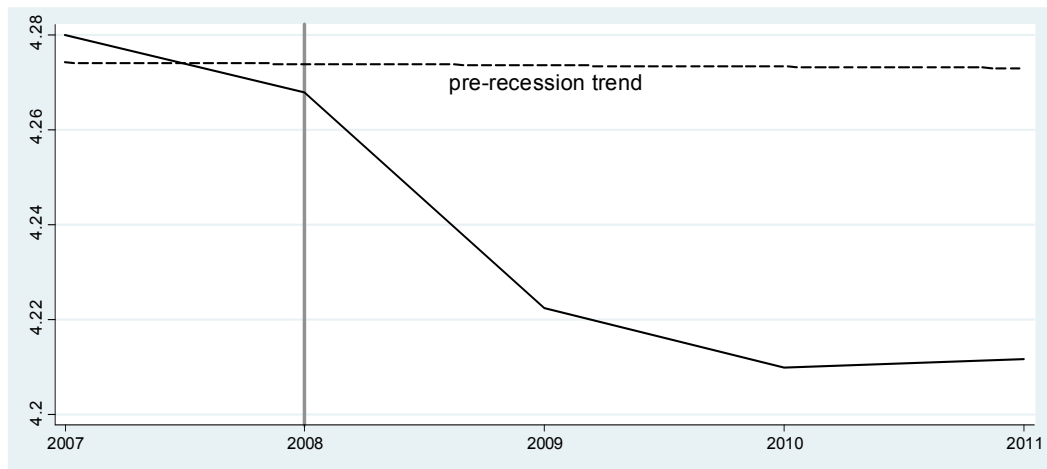
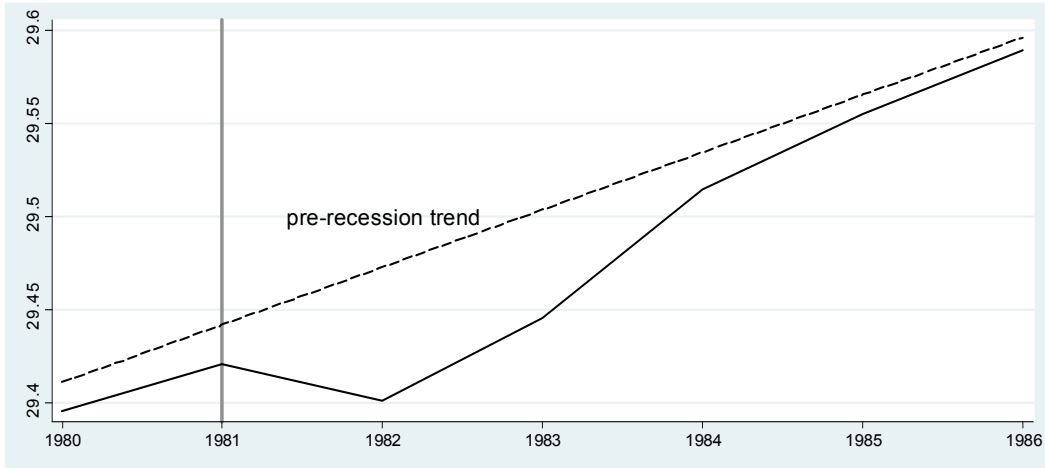


Figure 7. United States and the 1981 Recession
 a. Log of Real GDP



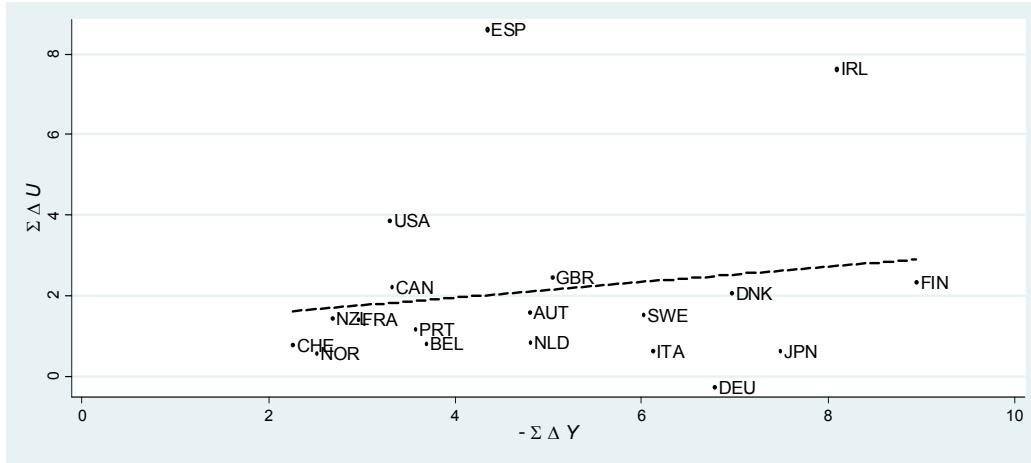
b. Unemployment Rate



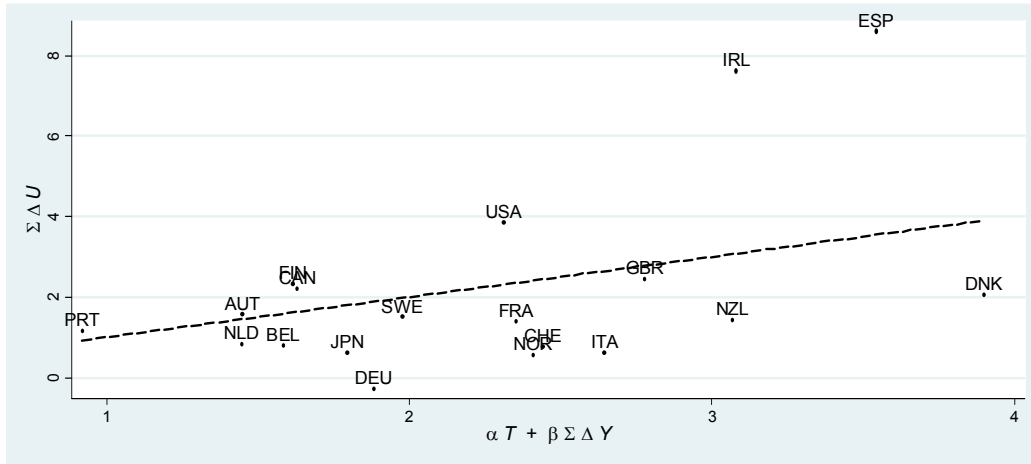
c. Log of Employment-to-Population Ratio



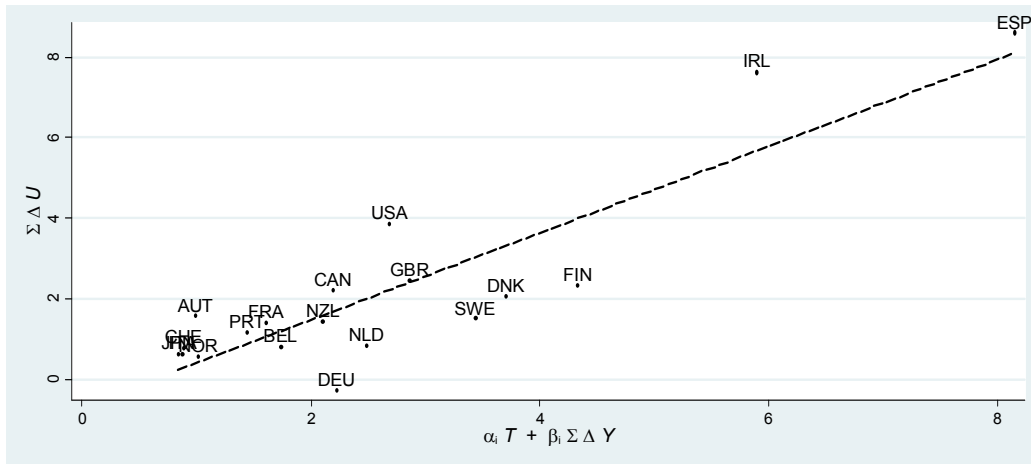
Figure 8. The Great Recession: Peak-to-Trough Output and Unemployment Changes
 a. Simple Scatter Plot



b. Adjustment for T

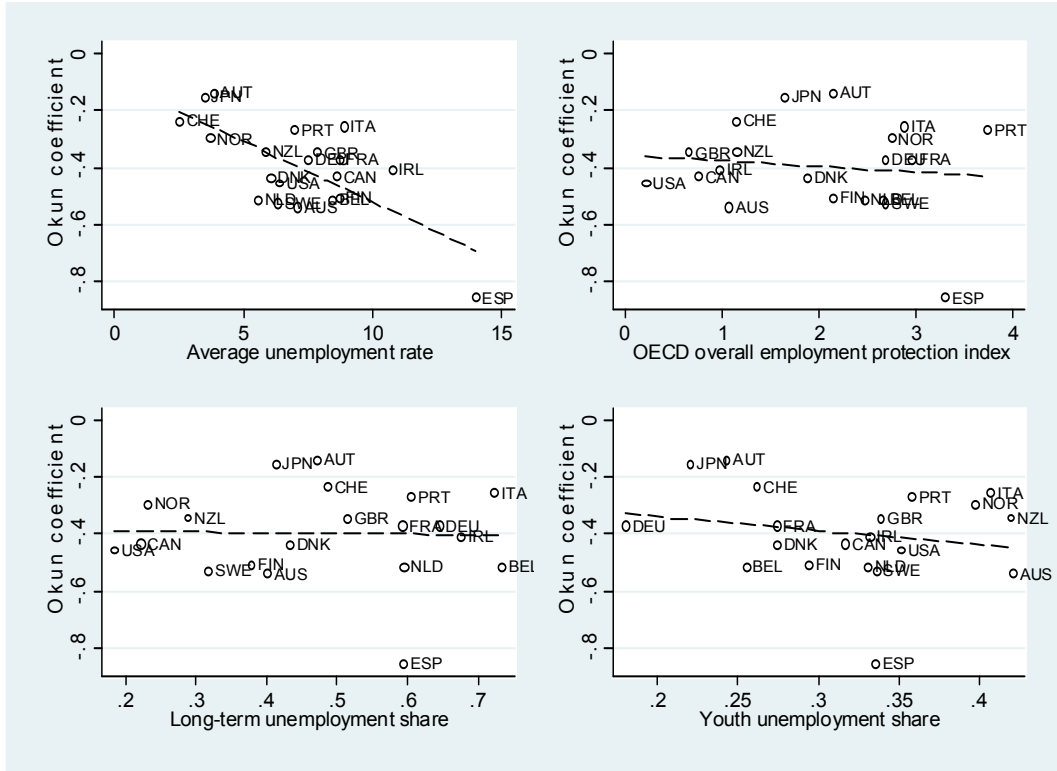


c. Adjustment for T and Country-specific Okun Coefficients



Notes: $\Sigma \Delta U$ and $\Sigma \Delta Y$ denote the cumulative peak-to-trough change in the unemployment rate and in the log of real GDP, respectively. T denotes the duration of the recession (peak to trough in quarters). α_i and β_i denote country-specific Okun coefficients.

Figure 9. Explaining Cross-Country Variation in Okun Coefficients (Okun Coefficient vs. Candidate Variables)



Notes: Average unemployment rate denotes 1980-2011 mean. OECD overall employment protection index denotes 1985-2011 mean based on available data.